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JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXIX.

INDEX.

Actinism. By Chas. F. Himes.......... 345
Allen, Harrison, Electricity in Medicine.......... 310
Annual Summary of Engineering and Industrial Progress, for 1884..... 144
Asphalt Pavements, Curious Effect of.......... 501
Atomic Weight of Carbon.......... 18

Bolts and Nuts. Standard Dimensions.......... 234

Book Notices:
  Abbott, Arthur V. Testing Machines, etc.......... 78
  Whiting, J. H. C., The Philadelphia Insurance Chart.......... 78
  Anthony-Brackett, Elementary Text-Book on Physics.......... 78
  Eissler, Manuel. The Modern High Explosives.......... 236
  Phillips, J. Arthur. A Treatise on Ore Deposits.......... 236
  Le Van, W. B. The Steam Engine Indicator and its Use.......... 238
  Thurston, Robert H. The Materials of Engineering. Part III.. 333
  Trautwine, J. C., Jr. The Civil Engineer's Pocket Book, etc..... 495
  Grant Geo. B. Handbook on the Teeth of Gears, etc.......... 495
  Smith, Chas. A. Steam Making, or Boiler Practice.......... 495
  Mott, Henry A., Jr. The Fallacy of the Present Theory of Sound.......... 496

Carbon, Atomic Weight of.......... 18
Cast Iron, Decomposition of, by Heat.......... 500
Chase, Pliny Earle. Some Principles and Results of Harmonic Motion. 32
" " " Elementary Phyllotaxy.......... 39
" " " Experiments in Weather Forecast..........306, 408
Clouds, Constitution of.......... 501
Clouds, Light, of the Upper Atmosphere.......... 409
Colored Rings, Comparison of.......... 335
Cometary Indication of Cosmic Currents.......... 452
Cores for Melted Steel.......... 266

Cornut-Isherwood, On the Modifications of Tensile Strength and Ductility which Iron and Steel undergo when Heated between Certain Temperatures.. 257

Correspondence :
  New Theory of the Suspension System with Stiffening Truss. By A. J. DuBois.. 77
  Pumping Molasses. B. H. B.. 234
  Standard Dimensions for the Heads and Nuts of Bolts. By John C. Trautwine, Jr.. 234
Corthell, E. L., On the Tehuantepec Ship Railway.. 457
Critical Temperature and Pressure of Air.. 498

Delany's Fac-Simile Telegraph Transmission. By Edwin J. Houston 233
Divining Rod, The. By Rossiter W. Raymond..1, 103
Draught Gauge, A Simple Form of. By J. Burkitt Webb.. 450
DuBois, A. J. The Suspension System with Stiffening Truss.. 77

Electric Conductibility of Distilled Water and Glass.. 456
Electricity in Medicine. By Harrison Allen.. 310
Electro-Metallurgy. By Nathaniel S. Keith.. 80
Electromotors, Alpine.. 39
Error by Maxwell, An.. 39

Fac-Simile Telegraphic Transmission, Delany's. By Edwin J. Houston 233
Fac-Simile Telegraphy. By E. J. Houston.. 490
Fire Hazards in Textile Mills. By C. John Hexamer.. 372
Fluid Circulation of the Sun's Mass.. 449
Formene, Use of as a Cooling Agent.. 500
FRANKLIN INSTITUTE—Additions to Library..241, 337, 503
  " " Proceedings of Stated Meetings.....79, 154, 239, 336, 423, 499
  " " Board of Managers, Annual Report of (1884)... 154
  " " International Electrical Exhibition. Reports Board of Examiners. See *Supplements*.
  " Committee on Science and the Arts. Report on the Metzler and Burrell Lantern.. 332
Frazer, Persifor. The World's Industrial and Cotton Centennial Exposition.. 425
Fritts, C. E. On the Fritts Selenium Cells and Batteries.. 221
Fruitful Grain, A.. 424

Gelatine, Explosive, Spontaneous Decomposition of.. 121
Gieseler, E. A. On Tidal Theory and Tidal Predictions.. 161
Gunpowder, Flashing Tests of.. 38

Harmonic Motion, Some Principles and Results of. By Pliny Earle Chase.. 32
Hexamer, C. John. Fire Hazards in Textile Mills.. 372

High Pressure Steam, Economy in the Use of. By W. Barnet Le Van........ 396
Himes, Chas. F. Actinism........ 345
Houston, Edwin J. Glimpses of the International Electrical Exhibition........ 40, 122, 189, 320, 409
" " Synchronism........ 295
" " Fac-Simile Telegraphy........ 490
" " Delany's Fac-Simile Telegraphic Transmission... 233

Infra-red Rays and Bands........ 31, 188
Intellectual Work, Influence of, on the Elimination of Phosphoric Acid........ 238
International Electrical Exhibition, Glimpses of. By Edwin J. Houston. (Telephones)........ 40, 122, 189, 320, 409
International Electrical Exhibition, Reports of Board of Examiners: V, VI and VIII, Electric Lamps; XIV, Batteries; XVIII, Underground Conduits; XIX, Electric Telegraphs; XXI, Fire and Burglar Alarms and Annunciators; XXIV, Electro-Dental Apparatus; XXVII, Applications of Electricity to Warfare; XXX, Machinery and Mechanical Appliances........ See SUPPLEMENTS.
Isherwood (Cornut and). On the Modifications of Tensile Strength and Ductility which Iron and Steel undergo when heated between Certain Temperatures........ 257
Isochromatic Photography. By Fred. E. Ives........ 367
Ives, Fred. E. Isochromatic Photography........ 367

Japanese Colony in Germany........ 102

Keith, Nathaniel S. Electro-Metallurgy........ 81
Krakatoa, Present Condition of........ 232
" Wave Velocity of........ 500

Lantern, Metzler and Burrell's Railway Signaling, Report on........ 332
Le Van, W. Barnet. Economy in the Use of High Pressure Steam........ 396
" " Modern Railroad Facilities........ 267
Liebig's Statue, Cleansing........ 266
Light, Influence of, on Tissues without Chlorophyll........ 238
Lightning, Globular........ 143

Magnetic Plates........ 335
Magnetism (Terrestrial) at Paris........ 29
Medicine, Electricity in. By Harrison Allen........ 310
Mining Problem, A........ 305

Natural Gas, Reports on the Utilization of........ 48
New Orleans World's Fair, Comments on. By Persifor Frazer........ 425

Optical Experiment........ 395

Pendulum, Deviations of, in Mexico........ 424
Photography, Isochromatic. By Fred. E. Ives........ 367
Phosphoric Acid, Influence of Intellectual Work on the Elimination of........ 238
Phyllotoxy, Elementary. By Pliny Earle Chase........ 39
Pneumatic Tubes........ 498
Pumping Molasses........ 234

Railroad Facilities, Modern. By W. Barnet Le Van........ 267
Raymond, Rossiter W. The Divining Rod........1, 103
Refractory Brick, New........ 121
Relation between Molecular Weight and Velocity of Evaporation........ 501
Ronkar's Theorem........ 501

Selenium Cells and Batteries. By C. E. Fritts........ 233
Selenium, On the electromotive action of illuminated, discovered by Mr. Fritts. By Werner Siemens........ 453
Sellers, Coleman. The Tercentenary Celebration of the University of Edinburgh........ 19
Ship Railway, Tehuantepec. By E. L. Corthell........ 457
Siemens, Werner. On the electromotive action of illuminated Selenium, discovered by Mr. Fritts, of New York........ 453
Solar Phenomenon in Switzerland........153, 235
Solar Protuberances, Observations of........ 494
Solar Rotation, Elements of........ 395
Spectra, Infra-red Emission........ 188
Spontaneous Decomposition of Explosive Gelatine........ 121
Stage Effects, Special........ 335
Star Photography........ 188
Steam Boilers as Magazines of Explosive Energy. By Robert H. Thurston........ 30
Sulphurous Acid in the Atmosphere........ 334
Sun, Internal Temperature of........ 371
Sun, Motion of the........ 305
Sun, the Physical Constitution of. By Chas. A. Young........ 280
Sun's Mass, Fluid Condition of the........ 449
Synchronism. By Edwin J. Houston........ 295

Telegraphy, Delany's Fac-Simile........233, 490
Telephone, Private........ 47
Temperature, Internal, of the Sun........ 371
Tensile Ductility of Iron and Steel, On the Modification of, when Heated between certain Temperatures. By Cornut and Isherwood....257
Thurston, Robt. H. Steam Boilers as Magazines of Explosive Energy 30

Tidal Theory and Tidal Predictions. By E. A. Gieseler...................... 161

University of Edinburgh. The Tercentenary Celebration of. By Coleman Sellers 19

Venus, Contour of... 489
Venus, Polar Spots on... 489

Waterproof Cement for Paper.. 305
Weather Forecast, Experiments in. By Pliny Earle Chase............306, 408

Young, Chas. A. Physical Constitution of the Sun.............................. 280

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THE DIVINING-ROD.*

BY ROSSITER W. RAYMOND, PH.D., New York City.

[A lecture delivered at the International Electrical Exhibition, September 18, 1884.]

The extent to which the divining-rod is still used in this country for the detection of hidden treasure, mineral veins, or springs, is much greater than educated persons would be likely to suppose. For many years wells have frequently been located by its aid in New England, where the belief is widely extended among the farmers that in the hands of peculiarly gifted persons this instrument possesses special virtue. Large numbers of the oil wells of Pennsylvania have been bored at points designated by the so-called "oil-smellers." More than one adept with this instrument is practising now in the Western mining region. I encountered, a few months ago, in Southern Colorado, a party of capitalists who were accompanied by such an expert, and whose purpose was to discover a mine, by his aid, and to buy the property thus made valuable. Still more recently, a paragraph in the Tombstone *Epitaph*, of Arizona, announced that a party of gentlemen from Chicago, whose names were given, had been scouring over the hills in the neighborhood of Tombstone, for more than a week, in company with an expert of Colorado, who had been employed to ascertain "with his well-known divining-rod" the localities of mineral wealth, and who had declared the existence of large bodies of ore in at least two places not yet developed. It is also reported, with what truth I do not know, that the Central Pacific and Southern Railroad companies have employed the divining-rod successfully in the discovery of water, and have located by this means their artesian wells in the desert. Last, but not least, a small book entitled *The Divining Rod*, and published in Cleveland, in 1876, contains an essay on this subject, read before the Civil Engineers' Club, of the Northwest, at Chicago, in 1875, by Mr. Charles Latimer, a well-known engineer who has had charge of several important railways, and who testifies in the most unqualified manner to the virtues of the divining-rod as a means of determining the position and the depth of subterranean water-courses, and claims to have discovered certain new and important laws of its operation connecting if not identifying it with the force of electricity.

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* This lecture was originally presented as a paper before the American Institute of Mining Engineers, and is here republished, by permission, from the Transactions of that Society, vol. xi.

These circumstances, taken together with the fact that the "dowsers," or experts with the rod, still enjoy considerable local authority in Cornwall, and that believers in its efficacy may still be encountered among the German miners (although I think in that country the faith is more nearly extinct than elsewhere), certainly justify me in regarding this subject as one not solely of historical interest. Yet a consideration of its history and literature will throw important light upon the question, whether the phenomena which it has presented, and continues to present, are to be ranked under the head of self-delusion, deliberate deceit, or both; or, on the other hand, indicate, after all reasonable deductions for human error and credulity, a residuum of important scientific truth.

Before sketching the history of this instrument, it will be well to say a few words concerning its form, material, and use. Yet this is a work of no little difficulty. The immense literature of the divining-rod shows nothing more clearly than the boundless confusions and contradictions of its advocates and professors. Of the dozen different schools of practice, each is necessarily obliged to reject many of the asserted principles and certified facts put forward by the rest.

The most common divining-rod, perhaps, has always been a forked branch of witch-hazel in the shape of the letter Y. This wood may have been selected because it forks in such a way as to give two branches of equal size, or because of its supposed affinity for springs of water.

But other woods, such as peach, ash, pitch-pine, and even metals, have been recommended at different times, and different professors of the art have also varied the shape of the rod, employing sometimes a straight twig with a small fork only at one end, or an elastic twig or whalebone without any fork. The dowsing-rod used by the expert mentioned in the Tombstone *Epitaph*, is, I believe, an instrument made of two prongs of whalebone united in a stem which terminates in a case similar to a rifle-cartridge. The contents of this case are a secret. (Similar cases, used in the Middle Ages, are said to have contained mercury.) This rod, like the ordinary forked hazel switches, is held in the two hands, each grasping the extremity of a prong, with the fingers closed not too tightly and the palms upward, the shank or stem of the rod being horizontal or vertical, or variously inclined, according to the principles of the practitioner. When carried in this manner by the operator, walking over the surface of the ground, the rod is said to turn or dip above treasure, mineral veins, springs, etc.; but there is an elaborate and complicated science based upon the various degrees, directions, and force of this dipping. Unfortunately the rules as determined by one or another celebrated operator have been found not to work for his rivals or successors, so that each authority lays down rules of its own. The straight rods were either balanced in various ways on one or both hands, or sprung bow-like between the two hands. The most peculiar rod described in ancient books was made of two pieces of wood, one of which was pointed and the other provided in the end with a socket. This rod being delicately held was said to indicate the presence of the object sought for by a peculiar revolution of the point in the socket.

An inquiry into the uses of such rods leads us at once to the history of our subject, in the study of which it will appear that divining-rods were first used in antiquity mainly or wholly for moral purposes; that in the Middle Ages their employment was for a long period confined to the discovery of material objects; that towards the end of the seventeenth century the moral use was again asserted, and that in the eighteenth century the divining-rod was relegated to the material sphere, and assumed the comparatively modest functions in the discharge of which it still lingers among us.

I would recommend to those who have not the means of an extended research the perusal of the book of Professor Fiske, of Harvard, on *Myths and Myth-makers* (Boston, 1873), in the second essay of which, on *The Descent of Fire*, this subject is treated in the light of comparative mythology; also the work of Louis Figuier, *Histoire du Merveilleux dans les Temps Modernes* (Paris, 1860), half of the second volume of which is devoted to the divining-rod; and, finally, the book of Chevreul, *La Baguette Divinatoire* (Paris, 1853), which is a conclusive summary from the standpoint of modern science and experiment. I do not mention the work of Mr. Baring-Gould, *Curious Myths of the Middle Ages*, which Professor Fiske compliments with frequent quotations, for the simple reason that Mr. Baring-Gould's essay on the divining-rod is made up almost wholly of portions of Figuier's work, often translated *verbatim* and without credit. A brief, interesting, and impartial discussion of the divining-rod from the standpoint of the Middle Ages, together with a curious engraving illustrating its use, will be found in the well-known work of Agricola (*De Re Metallica*, Basle, 1546), published in the sixteenth century both in Latin and in German, copies of which, though not very common, are still to be met with in the antiquarian bookstores of Europe. I believe the Library of the School of Mines, of Columbia College, contains a German copy. In the preparation of this paper I have made use of the Latin edition, which is the only one in my possession. An excellent summary of the subject, containing many curious details, will be found also in Professor Moritz Gaetzschmann's *Auf-und Untersuchung der Lagerstätten* (Freiberg, 1857). The Brooklyn Library contains a copy of a work entitled *Jacob's Rod: A Translation from the French of a Rare and Curious Work, A. D.* 1693, *on the Art of Finding Springs, Mines, and Minerals by means of the Hazel Rod. To which is Appended Researches with Proofs of the Existence of a More Certain and Far Higher Faculty, with Clear and Ample Instructions for Using it.* Published by the Translator: Thomas Welton, 13 Grafton street, Fitzroy Square, London. This book was published, I believe, in 1875. The title-page bears no date. The original French treatise, the translation of which occupies the first part, is probably the one entitled *La Verge de Jacob, ou l'Art de trouver les trésors*, which Figuier (*Histoire*, etc., vol. ii., p. 257) speaks of as well-known to the adepts in occult sciences, and Chevreul (*La Baguette*, etc., p. 30) mentions as an example of the use of the term "Jacob's rod," in those sciences, to signify a rod possessing marvellous properties. The origin of this signification will be found in Genesis, xxx. I suspect that neither Figuier nor Chevreul had seen this book; both of them fail to give either the name of the author or the date of publication, an omission especially noticeable in the case of Chevreul, who is usually both full and careful in his references. The translator gives the date as 1693, and names the author as M. Baritel. Of the fidelity of the translation I have no guaranty except internal evidence, from which I judge that it is honest rather than intelligent. This translator, Mr. Walton, is himself a mesmerist and electro-biologist, and declares his wife to be possessed of clairvoyant powers, of the exercise of which he believes the discovery of water, metals, etc., to be but one sub-division. The object of his translation and "addenda" is to connect the ancient phenomena of rhabdomancy, the observations and theories of Reichenbach, the fanciful speculations of Bulwer-Lytton, and numerous modern wonders (accounts of which he extracts from the *Spiritual Magazine*), and his own and his wife's alleged experience.

To the works above named I am indebted for nearly all the facts cited in this paper, and for many quotations made at second hand.

Professor Fiske, following Dr. Kuhn, whose treatise on the *Descent of Fire* was published in Berlin in 1859, traces the divining-rod to a wide-spread Aryan myth, connected with the forked lightning. Without going so far back, we may find in written history many evidences of the use of the rod, not only as a symbol of earthly power, but also as the instrument of supernatural effects, and particularly of divination. It will be remembered that the Egyptian sorcerers confronted by Moses carried rods, as Moses and Aaron also did. The prophet Hosea denounces the use of rods for divination by the Jews (Hosea 4:2). According to another prophet (Ezekiel 21:26) the King of Babylon consulted rods or arrows to decide his course. The Scythians, Persians, and Medes used them. Herodotus says that the Scythians detected perjurers by means of rods. The word *Rhabdomancy*, originated by the Greeks, shows that they practised this art; and the magic power of the rods of Minerva, Circe, and Hermes or Mercury, is familiar to classical students. The *Lituus* of the Romans, with which the augurs divined, was apparently an arched rod. Cicero, who had himself been an augur, says in his treatise on divination, that he does not see how two augurs, meeting in the street, could look each other in the face without laughing. At the end of the first book of this treatise he quotes a couplet from the old Latin poet Ennius, representing a person from whom a diviner had demanded a fee as replying to this demand, "I will pay you out of the treasures which you enable me to find." This ancient joke, by the way, has been adopted in all seriousness by the "oil-smellers" of Pennsylvania, who, as I am informed, are accustomed to locate oil wells on precisely this condition, receiving nothing if the well proves unsuccessful, and fifty dollars if oil is struck.

Marco Polo reports the use of rods or arrows for divination throughout the Orient, and a later traveler describes it among the Turks. Tacitus says that the ancient Germans used for this purpose branches of fruit-trees. One of their tribes, the Frisians, employed rods in church to detect murders. Finally, if we may trust Gonsalez de Mendoza, the Chinese, who seem to have had everything before anybody else, used pieces of wood for divination.

Thus we perceive that the application of the divining-rod in historical antiquity was mainly or wholly moral; that is, it was employed to detect guilt, decide future events, advise courses of actions, etc. There are but two passages which have been quoted to prove its use for physical purposes: one from Ctesias (*apud. phot. bibl. cod.*) who speaks of a rod of the wood *Parebus*, which attracted gold, silver, other metals, stones and several other things; the other from Cicero (*De Officiis*, lib. i.) who says, "If we could obtain with the so-called divine rod everything pertaining to food and clothing" (*ad victum cultumque*), etc.

On the other hand, the silence of many authors is significant, as Chevreul has pointed out. Varro does not mention the use of the rod for the discovery of subterranean waters or metal. Vitruvius, discussing the means of discovering springs, says nothing of it. Pliny, in Book xxx. of his Natural History, omits it from his enumeration of magical arts and methods, and in Book xxxi., describing (after Vitruvius) the means of discovering springs and in Book xxxiii., describing explorations for metals, is equally silent concerning it. Columella, Palladius and in the sixth century Cassiodorus are likewise dumb, though the latter in one of his epistles (*Thodoric*, liii.) extols the utility of the professional water-discoverers. Even as late as 1569, a book printed in Orleans (*L'art et science de trouver les eaux et fontaines cachées sous terre autrement que par les moyens vulgaires des agriculteurs et architectes*, par Jacques Besson, Dauphinois, mathematicien) contains no allusion to the rod. It is a curious circumstance that this work emanated from Dauphiny, the home, a century later, of the most famous diviners and water-discoverers.

But the alchemistic literature brings the physical uses of the divining-rod to the front. The first mention is usually credited to the *Novum Testamentum* of Basil Valentin, a Benedictine monk and hermeneutic philosopher of the 15th century. But it must be remembered that the existence, even, of this man is not beyond doubt. It is attested by Gadenus (*Historia Erfordiensis*, 1675), who says that Basil was living at the convent of St. Peter's at Erfurth in 1413. Yet the *Testamentum* was actually first printed at the beginning of the 17th century, though manuscript copies had been circulated earlier. Of these, Chevreul possesses one (a French translation) dated 1651, and from it quotes the famous passage according to which, at the time of the writer, the divining-rod was worn in the belt or the hat and was used to discover metals. Basil describes seven varieties of the rod, according to its different motions.

Whatever its antiquity, the use of the rod to discover hidden treasure or metallic ore became general in Germany, and was extended thence through Flanders, England, Sweden, France, Italy and Spain, before the end of the 17th century. It must be remembered that in those days the practice of burying money and plate was universal. A rod that would discover buried treasure only would, at the present time, be of comparatively little value. We know well enough where the large masses of gold and silver are piled. It is not ignorance, but bolts and bars, that prevent our getting at them; and a large class of the diviners of the Middle Ages would be obliged, if they lived to-day and practised their profession, to become burglars or cashiers.

The scientific explanation of the divining-rod at this period, like the scientific explanation of nearly all facts in chemistry and physics, was "affinity," a word under which was concealed a little science together with a vast amount of ignorance and superstition. Philip Melanchthon (1497–1560), the friend of Luther, adopted this theory to explain the effects of the divining-rod. We must confess that in an age when the attraction of the magnet for iron and of electrified amber for light bodies was known, but not understood, there was no necessary absurdity in supposing that similar phenomena might be exhibited by other classes of substances. And this natural presumption, joined with the inherent credulity of ignorance and the tendency to generalize upon imperfect data, caused a very general acceptance of the alleged operations of the divining-rod as true, and consequently the promulgation of crude quasi-scientific theories to account for it. On the other hand, it must be remembered that the belief in demonic agencies was still active and all-pervading, so that when facts could not be scientifically explained they were at once referred to witchcraft or to the devil direct. So long as the discussion remained within the field of science it was conducted with courage and candor; but when it entered the demonic domain, the boldest philcsopher, unless he were willing to sell his soul to Satan, became dumb. This may explain the attitude of the great Agricola (*De Re Metallica*, lib. ii.), a keen observer and wise reasoner, who, after saying that the alleged virtues of the divining-rod are subject to much dispute, and stating both sides of the dispute with admirable clearness, demolishes in a few words the supposed analogies of magnetism and electricity, but declares that if the divining-rod derives any power from spells and incantations, that is a matter neither permissible nor agreeble for him to discuss. He proceeds, moreover, to assert as the general result of experience in his time that the professors of the divining-rod, though they sometimes succeed in discovering veins, quite as frequently fail, and have to dig like other people if they wish to find anything. Wherefore, he advises the respectable and sober miner to study the indications of nature, and then dig at once, without further fooling. In the quaint woodcut which accompanies this passage a miner is represented in the background as cutting his hazel twig; while another in the foreground is proceeding with it in due form for the discovery of the mine; and (whether in sarcasm or not, I do not undertake to say) at the very point to which the latter is steering, two of Agricola's "good and sober" miners have already found ore by the homely process of digging.

Paracelsus (1495–1541) condemns in his works, as uncertain, illusory and unlawful, the use of the rod. His disciples did not uniformly agree with this view. Goclenius, author of *Essays on the Virtue of Plants and the Unguent of Arms*, believes in the efficacy of the rod and does not condemn its use. Libavius, author of the *Syntagma arcanorum chimicorum* (died 1616) believed in it from experience, and explains its action by sympathetic affinity. This theory, already announced by Melanchthon, was also held by his son-in-law Peucer, by Porta (*Magia Naturalis*, 1569, lib. xx., cap. viii.), by Keckermann (1573–1609, *Systemata Physica*, lib. i., cap. viii.) by the author of one of the discourses published with those of Maiolus, Bishop of Volturara (1614) and by Michael Mayer, the prolific author of alchemistic allegory (*Verum inventum, hoc est Munera Germaniæ*, cap. iv.) who, describing the invention of gunpowder in Germany and the use of hazel-charcoal in its original manufacture, mentions the sympathy which hazel-wood has for metals, and its consequent employment in the form of the divining-rod.

On the other hand, the Jesuit father Laurentius Forer (*Viridarium philosophicum seu disputationes de selectis in philosophiâ materiis*, 1624) condemns the use of the rod as a superstitious practice. We must distinguish therefore three different views of the question; two of which accepted the efficacy of the rod as proved, and ascribed it respectively to a physical property of the rod, and to demonic agency, while the third discredited the alleged facts, and pronounced the practice to be a superstition.

A fourth view was indeed advanced, according to which the operator, as well as the rod, was the recipient of a divinely-given faculty. It was no doubt with the purpose of avoiding the odium attached to dealings with the Evil One that the professors of this science, particularly in Germany, surrounded it with ceremonies and formulas of a highly pious character. It is true that the rules sometimes prescribed for the cutting of the twig partook largely of heathen sorcery and astrology. They were indeed, to some extent, unconscious reminiscences of the old Scandinavian, and even of the Aryan, mythology. But this was atoned for when the rod was duly Christianized by baptism, being laid for this purpose in the bed with a newly baptized child, by whose Christian name it was afterwards addressed. The following formula, cited by Gaetzschmann, may serve as an example. "In the name of the Father, and of the Son, and of the Holy Ghost, I adjure thee, Augusta Carolina, that thou tell me, so pure and true as Mary the Virgin was, who bore our Lord Jesus Christ, how many fathoms is it from here to the ore?" In this case, the rod was expected to reply by dipping a certain number of times, corresponding to the number of fathoms.

Such devices, however, were not everywhere successful in diverting from the practitioners of this occult science the evil name of sorcery. A striking and pathetic instance is furnished in the seventeenth century by the history of the Baron and Baroness Beausoleil. The Baron, born in Brabant, devoted himself to mineralogy and mining, and became, undoubtedly, one of the foremost mine-engineers of his time. He visited and studied the mines of Germany, Hungary, Bohemia, Tyrol, Silesia, Moravia, Poland, Sweden, Italy, Spain, Scotland, England and France. The emperors Rudolph and Matthias appointed him counsellor and commissary-general of the mines of Hungary. The archduke Leopold made him director of the mines of Tyrol and Trent. The dukes of Bavaria, Neuburg, and Cleves gave him the same title. Finally, the Pope did the same for all the papal states. He appears to have amassed from these various employments a considerable fortune.

In 1600 he was engaged by the comptroller-general of the mines of France to open mines in Languedoc and some other provinces, and in 1626 this commission was still further extended. During this period he met and married his wife, who devoted herself with enthusiasm to his profession, studying and traveling extensively with him in Germany, Italy, Sweden, and perhaps Spain. They even made a voyage to the shores of the New World. In 1627 their house was robbed under the legal forms of search on the charge of sorcery preferred by a local official. Their loss was estimated at one hundred thousand crowns. They easily obtained acquittal of the charge; but it is an instructive commentary on the justice of the time that they never were able to recover their property. They went to Hungary, but returned to France in 1632 under a new commission from Louis XIII. In this year the baroness, who was an accomplished author, published an account of one hundred and fifty mines already discovered in France, and of some medicinal springs. They expended, in further explorations, nearly the whole of their fortune, but were unable, in the face of their jealous rivals and enemies, to obtain from the government the grants which had been promised them, and by means of which they expected to reimburse themselves. Finally, the baroness published a work, addressed to Richelieu, and entitled *The Restitution of Pluto* (reprinted at Paris in 1779), in which, with eloquent indignation, she declared the deserts of her husband and herself, and asserted their right to the rewards promised them, urging the cardinal-minister at the same time, by every consideration of the glory and greatness of France, to encourage the development of its mineral resources. Unfortunately, in this work she furnished new material for the slanderous accusation of sorcery. In magnifying the art of discovering mines and springs, and the skill required for this purpose, she gives a description of the means employed, showing that these hidden treasures are to be detected,

1. By digging, which is the least important way;
2. By the herbs and plants which grow above springs of water;
3. By the taste of the waters which flow from them;
4. By the vapors which arise from them at sunrise;
5. By the use of sixteen scientific instruments and of seven rods (the seven rods of Basil Valentin) connected with the seven planets, etc.

The first four means were undoubtedly real and really employed. Under the fifth head we have an illustration of what is so common in the alchemistic and other mediæval writers, namely, the covering of the facts of nature and the methods of investigation with assumed mystery, to hide them from the vulgar. So long as the baron and baroness were spending their own money for the good of the State, they were permitted to go on, and even received complimentary notices from time to time, which, indeed, could not be withheld from persons of such eminent reputation. But when they became troublesome in their demands for more substantial favors and came into collision with the "rings" which infested the kingdom, the charges of sorcery renewed against them furnished a convenient pretext for putting them ont of the way. Richelieu may even have supposed that he was behaving in this case with lenity, since instead of having them burned to death, as he did with another sorcerer of the same period, he only put the baron in the Bastile (1642) and his wife in Vincennes, where they soon (about 1645) died in destitution and misery, victims not so much of the superstition as of the corruption of the times.

It will be noted that the treatise of the baroness did not claim from the divining-rod any moral virtue. What the Beausoleils appear to have done for this instrument was to bring forward its use in the discovery of springs as well as metals. The literature of that period seems to ignore in the main any powers of the rod in prophecy or moral discrimination.

The Jesuit father Cæsius (*Mineralogia*, 1636) inclines to deny the efficacy of the rod.

Robert Fludd (*Philosophia moysaica*, 1638) after mentioning the sympathy existing between the crab or oyster and the moon, between the rue and the fig-tree, between myrtle and the pomegranate, adduces as an instance of similar sympathy between plants and minerals the dipping of a hazel-rod over a vein of silver or gold.

The celebrated chemist, Rudolph Glauber (*Pars seconda Operis min-*

eralis, 1652) affirms from experience, and attributes to a physical property, the efficacy of the rod in exploring for metals.

The Jesuit father, Jean François (*Science des Eaux*, 1653) seems to admit the power of the rod to discover springs, but condemns its use.

The erudite Jesuit father, Kircher (*De Arte Magnetica*, 1654, *De Mundo Subterraneo*, 1678) having proved by experiment that rods of wood alleged to be sympathetic with certain metals, were, when balanced upon pivots, not at all affected by the proximity of these metals, concluded that the sympathy was chimerical. In his later work he declared roundly that if the movement of the rod did not proceed from a joke or a cheat on the part of the operator, it was not natural, and ridiculed those who fancied it could be caused by a vapor disengaged from the metal.

Edo Neuhusius (*Sacrorum fatidicus*, 1658) believes in the working of the rod, and attributes it to a sympathy, or to the stars, or some other cause.

The Jesuit father, Gaspard Schott (*Physica curiosa*, 1662), pronounces the use of the rod superstitious, or rather diabolical. But he adds in a footnote that pious and honest men have assured him both with regard to the turning of the rod and with regard to the striking of the hours by a ring suspended within a glass (*pulsum annuli filo intra scyphum suspensi et horas indicantis*), that the experiment does not always succeed, and hence he will not assert that the demon is always acting. The argument appears to be, that if the devil had it in hand, it would not fail. The pious and honest men aforesaid also protested that the phenomenon was natural and not due to fraud or fancy. "*Sed nondum persuaserunt*," pithily concludes Schott. The passage is noteworthy as containing a reference to the wonderful pendulum, which became, at a later day, the subject of scientific treatises, and still survives as a puzzle and amusement for children for all growths.

Sylvester Rattray (*Theatrum sympatheticum*, 1662) believes in the sympathy of vegetables with minerals. According to him, the hazel is suitable for the discovery of silver, wild pine for lead, olive and palm for gold and silver.

It was in 1666 that Robert Boyle put the question as a member of the Royal Society of London, whether the divining-rod is really moved by the proximity of metal—a pertinent inquiry which no one seems to have answered by authoritative and thorough experiments, unless we may accept as sufficient those of Kircher above mentioned. The accumulation of contradictory testimony from witnesses of all degrees of competency went on.

Matthias Willenius, a German author, published in 1671 or 1672 a book called *A True Account of the Rod of Mercury*, in which, as the title indicates, he appealed to astrology for the partial explanation of his theme, asserting that the influence of the stars under which the operator is born, contributes to the turning of the rod over metals, "by the effect of the harmony established between heaven and earth."

Frommann (*Tractatus de fascinatione*, 1674) says that, after long hesitation, he has decided that the use of the rod is lawful.

The Jesuit father, Dechales (*De Fontibus naturalibus*, 1674), inclines to the same opinion, and speaks of the hazel as having been in all times (*omni tempore*) used as an index to springs. This is a curious illustration of the rapidity with which a tradition may come to be considered immemorial. In fact, if we except the striking of the rock in the desert by Moses—which is certainly not a case in point—the first trace of the use of the rod for discovering springs, is in the works of the Beausoleils, scarcely fifty years before Dechales wrote his treatise.

Le Royer, a lawyer of Rouen, published in 1674 his *Traité du bâton universal*, and in 1677 his *Traité des influence et des vertus occultes des êtres terrestres*. He declares that the rod by its sympathetic virtue can discover all hidden objects, metals, springs, etc. But he ascribes to it no moral power.

The Abbé Hirnhaïn (*De typho generis humani, sive scientiarum humanarum inani ac ventoso humore*, etc., 1676) while scoffing at many received beliefs, admits without question the efficacy of the divining-rod.

St. Romain (*La Science naturelle degagée des chimères de l'école*, 1679) was one of the first believers in the rod to reject the sympathies and antipathies and to substitute the Cartesian corpuscular hypothesis—of which I shall have more to say hereafter.

Finally, the celebrated botanist, Ray (*Histoire des Plantes*, 1686), classed the divining-rod among superstitions.

This review of the literature of the subject has brought us to the end of an important period, namely, that in which the physical effects of the rod were exclusively discussed, its earlier uses for general divination having gone out of fashion and recollection. Indeed, any attempt to maintain these would have incurred the censure of the church, which would have settled at once the vexed question of agency by denouncing this unauthorized intrusion upon its spiritual prerogative as diabolic. This is indeed what speedily happened, as we shall see. The lost doctrine of moral power reappeared, not among the learned, but out of the obscure mass of the people. In the province of Dauphiny, in the south of France, the practice of the divining-rod, introduced perhaps by the Beausoleils, had become, fifty years after their death, an art followed by many experts, who were called *Hommes à Baguette.* They were employed to find springs of water, hidden treasure, mines, etc., and also to detect criminals, and even to settle disputes as to boundaries when the landmarks were gone. Two farmers, for instance, having a dispute as to the boundary between their farms, instead of going to a lawyer or judge, would send for a diviner. He walking over the disputed ground, would indicate by the dipping of his rod the spot where the old landmark formerly stood; and this decision was accepted without appeal. Considering the expense of litigation in all times, and the peculiar character of the justice which at that time was sold so dear and worth so little, we may fairly say that whatever be the merits of the divining-rod, the peasants of Dauphiny acted wisely in employing it.

In 1692 a mysterious murder was committed at Lyons. A wine merchant and his wife were found dead, lying in their cellar near the bloody axe with which they had been slain. A neighbor urged the authorities (who seem to have had no clue to the murderers) to employ a rich peasant of Dauphiny, already famous as an expert with the divining-rod. This man, Jacques Aymar by name, was sent for—or rather it was not necessary to send for him, since he proved to be already on hand in the city, by the time it was decided to engage his services. This fact is significant, as giving the key to what turned out to be an extraordinary piece of clever detective work. A careful analysis of the numerous official and other records of this case shows it to be quite possible that the diviner had obtained important clues before he was publicly set to work. He first demanded to be taken to the scene of the crime that he might get his "impression." This consisted in a sort of shuddering, accompanied with signs of agitation, pain and exhaustion, and manifesting itself besides in the dipping of his rod. This took place at the spot where the bodies had lain, the spot where the axe was found, and also in the shop above, at various points which he declared to have been occupied or touched by the criminals. Having thus obtained a thorough impression, after the fashion of a bloodhound getting a scent, he started, though it was night, and followed with his rod the alleged course of the fugitives, passing without hesitation through many unlikely places, as far as one of the gates of the city. Next morning he resumed the trail and tracked it to the house of a gardener, where he declared that the criminals, either two or three in number, had stopped. The gardener and his wife denied all knowledge of them, and Aymar, consulting his rod, declared that neither had touched the murderer. But the rod dipped violently over two young children of the house, who thereupon confessed that three men had stopped there the day before, and had drunk wine at a table, which, by the way, had also been indicated by the rod. The children said they had kept this a secret because they feared being punished for leaving the door unlocked while their parents were away. After some further delays and preliminary tests, the magistrates determined to let Aymar pursue the murderers. He declared that they had taken a boat down the Rhone, and he followed them with an escort in the same manner, landing from time to time at different points where he said they had stopped. His pursuit was continued for a number of days with various interruptions, the assigned causes of which seem to have been sometimes but pretexts, and permit the suspicion that the intervals were employed by him in getting information in other ways. However this may be, he finally brought up at the prison of Beaucoire, and after applying his rod in succession to the inmates, pointed out as one of the Lyons murderers a hunch-back, recently arrested for larceny. This man, being taken back to Lyons, was recognized at several points on the road as having passed just after the murder, and finally, frightened by the accumulated evidence against him, made a full confession, and was subsequently broken alive. The other two murderers Aymar professed to follow to the sea and at sea along the coast, until, as he alleged, they escaped from the kingdom.

So long as there was no doubt of Aymar's sincerity, this discovery of the criminal by the aid of the divining-rod seemed indeed marvelous. But it is not more wonderful than many detective operations in which the rod has placed no part; and it is easy to trace the possible or probable methods which he employed. If, for instance, during the period just preceding his engagement by the magistrates, he had, in coming to town from his residence, fourteen leagues distant, or in hanging about the town, where everybody was talking of the crime, picked up in any way the circumstances of the three fugitives entering the house where the children were, it is almost inevitable that he would have obtained also some general description of their appearance, and I need scarcely remark, that the subsequent tracking of a hunchback would be no very difficult matter. It should be added here, that the judges who sentenced the hunchback, explicitly declared that they attached no weight to the indications of the rod as direct evidence of his guilt, but condemned him wholly upon his own confession, confirmed by abundant circumstantial evidence.

But this achievement of the rod, attested as it was by official records and by the public confession and execution of the criminal, made a great sensation in France; and Aymar was called to Paris, where both the court and the savans interested themselves greatly in his mysterious powers. Many marvellous feats are reported of him there; but the shrewd and rigorous experiments of the Prince de Condé exposed the emptiness of his pretentions. It was Aymar's claim that his rod was sensitive to the particular object which he was at the time seeking. When he sought a given murderer the track of some other murderer would not divert it. When he was pursuing a criminal he could not be led astray by subterranean water or treasure. If he felt these things in passing, his feeling was nevertheless distinguishable from that connected with his intention, etc. He could, at will, seek any given object, and when doing so could not be deceived. Unfortunately for this claim the tests of the Prince deceived him very often. For instance, a purse of money was shown him, and after he had got his "impression" of it, it was taken out to be buried in the garden, but instead of burying it, the person who had it kept it in his pocket. Aymar proceeded to the garden, and, undisturbed by the immediate neighborhood of the money in the pocket of a bystander, located the spot where he said it was buried. In another case he detected the gold of the gilding of a chair which was covered so as to permit a glimpse of its ornaments, but he sat on a similar chair, and walked through a saloon containing many of them, all completely covered, without discovering any gold. In another case a window was designedly broken in a palace. Aymar was sent for to trace the thief, who, he was informed, had recently stolen some money from the palace. His rod promptly indicated the broken window as the road by which the thief had entered, and he proceeded to trace also the route of flight, although no such theft had ever occurred. But so long as these and similar failures were not made generally public, Aymar continued to enjoy much celebrity, and no doubt it was enough to turn the head of a peasant to be the object of such attention. Growing more audacious, he undertook to reveal character with his rod, and on one occasion, having received a fee from a gentlemen of the court, with the request that he would discover whether the gentleman's sweetheart was true to him, he sent for the lady's servant, and demanded of him another fee as a condition of certifying her virtue. Scandals of this kind became so bad that the Prince de Condé publicly exposed Aymar, and he returned to his home. On his way, however, in passing through a village he took occasion to designate five or six of the most respectable houses as the abodes of wicked women, which made a great uproar. I wish I could say that nothing more was afterwards heard of him; but unfortunately it appears that, as late as 1703, this man was employed during the civil war to point out with his divining-rod Protestants for massacre, under the plea of punishment for crimes they had committed.

We find connected with the exploits of Jacques Aymer a new theoretical explanation of the divining-rod. Many persons of more or less scientific training, not doubting the honesty of the man and the genuineness of the sensations which he manifested, cross-questioned him on the subject, and thus accumulated a mass of supposed data for the formulation of the natural law underlying these phenomena. It was at this time that the Cartesian philosophy was dominant in France, and the "subtle matter," "corpuscles," "animal spirits," and "vortices," of Descartes, furnished convenient hypotheses to explain almost anything. The two doctors of Lyons first supplied such hypotheses to the case Aymar, but the subject was treated at still greater length by the abbé de Vallemont, in his treatise on the divining-rod entitled *Physique Occulte*, and published in 1693. In this work he declares that by insensible transpiration particles escape continually from our bodies, that such particles pursue a vertical direction, and strike the divining-rod, which is thus caused to move up and down, assuming a line parallel to the path of the corpuscles. The holder of the rod receives corpuscular effluvia from other human bodies, and various substances, and communicates them through his pores to the rod, thus producing also a movement of revolution. The difference of the skin in different people results in various degress of susceptibility to particular impressions, but Aymar was, according to the abbé, possessed of an epidermis which could receive all kinds of impressions without confounding them. The abbé says that there is a difference of form among the corpuscular effluvia of springs, minerals, bodies of thieves those of assassins, those of naughty women, those of landmarks, etc.; in other words he recognizes the existence of aqueous matter, larcenous matter, murderous matter, etc., and the last named variety was the only one which produced upon Aymar very painful impressions. This was due, according to his scientific expounder, to the vehemence of remorse which pervades the corpuscles of an assassin. The fact asserted by Aymar that he had detected and followed the trail of a murderer twenty-five years after the murder, and the fact that in almost every instance he necessarily began his researches a day or two after the crime—to say nothing of the cases in which he determined the locality of the landmarks which had been missing for an immemorial period, forced the abbé to a wild hypothesis of the extraordinary levity of the corpuscles, by virtue of which they remained a long time suspended in the air in spite of rain, wind and even other corpuscles of later origin.

Father Lebrun, in a pamphlet on *The Illusions of Philosophers Concerning the Divining-rod,* printed at Paris in 1693, seriously refuted the system of Vallemont. This pamphlet was republished in the third volume of Lebrun's *Critical History of Superstitious Practices* (Paris, 1702).

But Father Lebrun and a large proportion of those who took part in the discussion rejected the scientific theory altogether, and attributed the facts to Satan. It was asserted that not only wicked people might obtain the divining power by a league with the devil, but that such an alliance might be made unconsciously, and that the power might be conferred upon an unwilling subject, as a means of ruin to his soul. Several cases are described at length, in which persons in whose hands the divining-rod pointed out springs, etc., had been by prayer and fasting and the help of their spiritual advisers, delivered from this dangerous gift. The authorities of the church favored this view, at least so far as any moral uses of the divining-rod were concerned. In 1701 the Inquisition of Rome condemned the divining-rod and all writings in support of it.

(To be concluded.)

ATOMIC WEIGHT OF CARBON.—C. Friedel (*Bulletin de la Société Chimique*, xli. 100) by burning diamond in oxygen found the atomic weight of carbon to be between 12,007 and 12,017, if the atomic weight of oxygen is assumed to be 16.—*Dingler's Journal*, April 9, 1884. C.

THE TERCENTENARY CELEBRATION OF THE UNIVERSITY OF EDINBURGH.*

TECHNICAL EDUCATION. THE MECHANIC ARTS ABROAD AND AT HOME.

BY COLEMAN SELLERS,
M. Inst., C. E., etc.; Professor of Mechanics in the Franklin Institute.

MR. PRESIDENT AND MEMBERS OF THE FRANKLIN INSTITUTE:

Our Secretary has advised me that I am expected to speak of my representation of this society at the tercentenary of the University of Edinburgh, to touch perhaps on technical education and say something of my impressions of the state of the mechanic arts in Europe as compared with the state of the same arts here. Any one of these subjects, might, without being exhausted, fill all the time I dare take in the programme of this evening, so my remarks on all of them must be of the most superficial nature. In regard to the University of Edinburgh —I found on my return home a paper which I will read to you:

UNIVERSITY OF EDINBURGH, *May*, 1884.

Sir:—We, the undersigned, in the name of the University of Edinburgh respectfully request that you will convey an expression of our cordial thanks to the FRANKLIN INSTITUTE, Philadelphia, for their courtesy and kindness in deputing you as their Delegate to attend the Tercentenary Festival of the University of Edinburgh, and for the congratulatory address which, by your hands, they honored the occasion.

Owing to the friendly co-operation of the FRANKLIN INSTITUTE, Philadelphia, and other celebrated societies, the Tercentenary Festival became the greatest Inter-Academical and International gathering of distinguished men that, perhaps, the world has hitherto seen. A grateful memory of that illustrious assemblage, and of those who composed it, will ever be cherished by the University of Edinburgh.

We have the honor to be, sir, your faithful servants,

JOHN INGLIS, *Chancellor.*
STAFFORD W. NORTHCOTE, *Rector.*
A. GRANT, *Principal.*

PROFESSOR SELLERS, etc.

With the exception of this letter, I have already reported to the Board of Managers of the Franklin Institute fully as to the performance of my duty of representing this Society at so important a celebration. It is perhaps not out of place now, however, to say that it was with feelings of sorrow that I took the place of Mr. Frederick Ransome, who had been appointed delegate, I being named as alternate. Domestic affliction was weighing upon Mr. Ransome and he could not undertake what would have been great pleasure to him under other circumstances.

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*Abstract of remarks made at the stated meeting of the Institute. Nov. 19, 1884.

I promised him that I would tell you that it gives him pleasure to attend to such matters for the Institute as are intrusted to him in London, and that he deeply regrets his inability to act as the representative of the Franklin Institute at the Edinburgh Tercentenary. I need scarcely say that I assured Mr. Ransome that we fully appreciated all that he has done for us.

You have all heard of the many notable persons who collected to do honor to a university, that has become celebrated during the three centuries of its life. The good people of Scotland living in the beautiful city of Edinburgh, spared no pains to render the stay of the delegates very pleasant. Agreeable as this attention was, it rather prevented any social intercourse among the visitors, and the only chance to see those who were present from many noted colleges and learned societies in all parts of the world, was at the dinners and entertainments prepared for that purpose. There, one could hear such men as Professors von Helmoltz, Virchow, and Elize, Count Ferdinand de Lesseps, Professor Pasteur, besides a host of notable men from the institutions of English speaking countries. The most imposing ceremony was the presentation of the delegates to the representatives of the University of Edinburgh. On some of the most noted the degree of LL. D. was conferred at the same time, and this presentation afforded the chance to connect each in person with the name he bore. At the banquet, Earl Rosebery told the story of the college when proposing the toast "the Lord Provost, Magistrates, and Town Council of Edinburgh." For it was their predecessors, three hundred years ago, who founded this college without the aid of king or noble. As the speaker remarked, it was well the king gave none of the help he had promised, as he had nothing to give. Had he bestowed aught on the University of Edinburgh, it would have been placed in the position of receiver of stolen goods, for the king could only have given by robbing others. It was the people of Edinburgh, who aided and supported the university, and to it flocked students from all parts of England and Scotland. Those came to it who could not enter the older colleges, for in it alone, among all, was there no sectarian qualification needed for entrance. The poor student bearing his bag of oatmeal for his winter support passed the house of John Knox, on Cannongate and perhaps bought his cheap books at the shop of Allen Ramsey on High street. Now, as then, no question is asked of him who enters and pays his modest fees. Through the years he can study and when he has tarried as long as his purse will permit, he can go into the world and use the mind-food he has consumed. It is only when he asks for a degree that he is examined to see if he has earned it. Very many of those who have been educated in the University of Edinburgh and who in after years have made their mark in the world have gone to that life work without graduating, perhaps to be honored by complimentary degrees when distinction had been achieved without the aid of a diploma.

After the foundation of the University of London, which is, like that of Edinburgh, free from sectarian requirements, there was some falling off in the attendance at the University of Edinburgh, the English institution taking its share of students. This, however, did not long continue and the attendance in Edinburgh is now over 3,000, more than half being students in the very excellent schools of Medicine. New and commodious buildings are being added to the college and the chief industry in Scotland's ancient capitol at this day, seems to be education. The direction of education so far as the University of Edinburgh is concerned, is like that of the other great seats of learning in Great Britain. It is confined to what they call the humanities; teaching the natural sciences, as in our technological institutions, is not yet much advanced in Great Britain. It is true, that there is a chair of engineering at Edinburgh, but I think it is more in name than of any practical utility as a means of teaching. I mean there are not many students who seek to be educated in engineering at that school. This leads me to say a few words on

TECHNICAL EDUCATION.

Sir Lyon Playfair, at the annual dinner of the Institution of Civil Engineers in London, answering, with Earl Granville, the toast "The Chief Seats of Learning of the United Kingdom," said that he had visited most of the technical schools of Europe and America, and he complimented the schools of our country saying that he was bound to admit that he had seen none so well equipped as in the United States; his version being, that "the Americans had foreseen that protection could not continue long to exist in their country, so they had established technological schools to meet the consequent competition of free trade." He then mentioned the Guild School which is starting in London, near the South Kensington Museum, and briefly alluded to work that is being done in Manchester, Leeds and some of the other manufacturing towns.

I cannot say that I accept the interpretation given by Sir Lyon Playfair as to the reason of the foundation of the great scientific schools of America. They seem to me to be the outgrowth of protection, the outgrowth of the advance in the trades brought about by protection and made necessary by the extended system of public education that has so long obtained here. Compulsory education is now being introduced into Great Britain, and is yet uncertain as to the best method of feeding the waters of the springs of learning to the young spirit thirsting for the draught, and at the same time to force it judiciously on those who have an hereditary distaste for such mental nourishment. It is not well for me to say over much about what is being done in teaching the sciences to the masses in Great Britain, but in Manchester and elsewhere I have seen some well-fitted schools. I have seen rooms fitted with spinning machinery close to the drawing school. I have seen where the art of dyeing is taught under the name of chemistry, where weaving too is taught, and all this in a city where the chief industry is the use of the spindle and the loom. Now with all due deference to the earnest men who have instituted these schools I must say to them, if the sound of my voice through the reporters this evening is to reach over the three thousand miles of water that separates us, that it will in time be found that trades must not be taught in schools that are intended to educate the masses. I doubt if they can be so taught to advantage. Technical education to be of the greatest advantage to the people in proportion to the money expended in the education, must be in the direction of " instructing without constructing." In other words, it will be found that the hands and eyes must be trained in the underlying principles. The use of tools must be taught as a means of educating the hands, and the mind at the same time; but not in teaching or restricting the teaching to some of the few trades that use those tools in common; and I would restrict the teaching to the use of hand tools in the lower schools. Drawing is being taught in a very thorough manner in many of the schools in Great Britain, and many of those schools are directly attached to factories and work shops. Much is said about a great town that has sprung up near to Chicago, which is wonderful as showing how a dreary waste of swamp land can be reclaimed and made the habitation of a large number of active workmen engaged in one trade. The counterpart of this can be seen on the beautiful banks of the Aire, in England. Here, Sir Titus Salt founded years ago at his factories, the town of Saltaire, with many streets full of good stone dwellings, with large and commodious buildings for schools and public entertainment, with good pavements on the streets, such pavements as would put to shame the streets of this city of Philadelphia. An ample library is at the service of all the operatives, and the drawing school is conducted on the best principles of training the hand and eye and teaching habits of close observation. It was a treat to visit this place and see the neatness that prevailed, and to feast the eye on the brilliant verdure of the beautiful Park that skirts the Aire, and to stand on the handsome stone bridge that spans the water close to the green fields and to see the three thousand operatives trooping back to work from their dinner, looking contented, well-dressed, and with faces indicative of a higher education than is to be seen in many of the English manufacturing towns. In France, Germany, and in fact all the European countries I visited, there is a vast amount being done in technical education, so much that it is becoming the general belief that the schools of Europe are now fitted to turn out full-fledged engineers. This is, I fear, a great mistake, and I think I can see plainly to what it is leading. I have seen a locomotive, for instance, that required for its con struction a specification covering the leaves of a large folio book of many pages, telling the maker how each minute part is to be constructed, regardless of the facilities that the maker might have to construct economically on his own system of shop sizes. The cylinders seem to be the work of one scientific expert on cylinders; the valve motion the work of another, the boiler was the brain work of a third, perhaps; and the whole brought together into one machine—well, I confess I know not how, but looking like too much science and not enough practice. Engineers are born, not made. Mozart was a musician above all others before the science of acoustics was known or understood. Great engineers have achieved their greatness without the aid of schools, but we know not how much more easy they might have done so, and how much more they might have accomplished could they have had the advantages of systematic technical education. No technical school can give experience and judgment; these come through work and close observation. The technical school must train the habits of thought in the right direction to avoid needless waste of energy, must teach how to work, not aim to take the place of skill and experience.

THE MECHANIC ARTS, ABROAD AND AT HOME.

In regard to the mechanic arts, in the direction that my own profession would prompt me to look, I can only say that the subject is too great to be more than touched on. Landing on a foreign shore, modes of transport for man and matter first claim attention. A few days in Liverpool, for instance, and a ramble among the great docks and store houses, gives food for much thought. First the *very good* smooth pavements enable the horses to draw heavier loads with less labor than with us, and just here the contrast with our own city is so painfully humiliating to us, that I dare not take the matter of pavements into thought this evening, for I would then have little else to talk about. Power cranes for handling goods either on the docks, in the warehouses, or on the road, are admirable in design, and are more numerous than with us. I cannot say that they are better, than can be obtained here, but the people have come to require them more generally. Passenger elevators or "lifts" as they are called in England, are slow and far from equaling what we consider needful.

It was from Liverpool that the first passenger train, drawn by a locomotive, made its way to Manchester in 1829, or thereabouts. The English locomotive does not look like anything that we have under the same name. They are to my taste very handsome machines, well built and neat in their freedom from extravagant ornamentation. The nature of the climate renders the need of protection to the men on the engine of less moment than with us, and the old "drivers" object to the more modern English locomotives, upon which small cabs are being now placed. The majority of English locomotives are inside connected, and have crank axles. They differ from the American locomotive in almost all essential points of construction. Plate or built up frames are universal; our bar frame not being used. The equalizing system universal with us is not attempted, or deemed advantageous. The whole system of cars, either for passengers or freight is different, and so far as the passenger service is concerned, is not to be compared with our own in comfort. Their light "coaches" are less steady than our heavier cars. To me it was always a delight when on one or another road I found the Pullman service in use, and yet I have been alone in a fine "drawing-room" coach while the ordinary, small, stuffy first-class coaches were filled with the natives who prefer their exclusiveness, I presume. As the locomotive department is so different in its conduct and its out-put from our own, one naturally notices the difference, and it will be well perhaps to confine my remarks to this subject, or at least to make it more prominent than any other. In the first place the manufacturers of locomotives cannot establish types and make them for sale in quantities. Each road has its own type of engine, and the builder must have his contract and be supplied with specifications before he can begin to work. On the other hand, the great roads of England employ talent of a high order in their locomotive department, recognizing the importance of a well designed and interchangeable system of service and the influence of the Superintendent of Locomotives, extends over all parts of the road where mechanical skill is required. The engine and the track are so intimately connected that they need be treated as a whole. Familiar as I was with the difference between the American and the English locomotive before I went abroad, I naturally turned my attention to the more recent developments in engineering in that direction. There are many great corporations controlling lines of travel in England, and it would be invidious to comment on one more than on another, as so much good work is being done by all.

On the London and Great Western, however, there has been attempted so radical a change from former practice that I may well take the work of its Locomotive Superintendent, Mr. Francis W. Webb, as the "example" this evening. Mr. Webb has compounded his engines, and he has kindly furnished me with very good photographs of his new engines, some of which I will show you this evening by means 'of the lantern on the screen. On my second visit to Crewe, where are the chief shops of the London and North Western Railroad, I had the pleasure of riding on the "Dreadnaught," the last of the perhaps fifty compounded engines that Mr. Webb has built. It ran well, steadily, and was as readily handled as any ordinary locomotive of the old type. We made sixty miles an hour up the heavy grade out of Crewe, and came down the same incline at what was said to be seventy miles an hour. The Dreadnaught has two pairs of driving wheels, the hind pair of wheels being on a straight axle and the cylinders connected with them being outside the frame, what we call outside connection. The cylinders are set well back on the engine and the valve motion is that known as the "Joy," which dispenses with eccentrics, gets its motion from the connecting rod and obtains the lap and lead from the cross-head. So far as I have now described the engine, it is as if it had but one pair of wheels, on one axle and a pair of cylinders to actuate that one pair of wheels. The forward drivers are placed on a crank axle, there being one crank only, in the middle of that axle, and to this is connected a rod from one single cylinder, placed immediately below the smoke-box; the front cylinder head being flush with the end of the smoke-box. This one cylinder operating the forward pair of drivers has an independent valve motion and drives the front wheels, without any reference to the hind ones, so far as rate of revolution is concerned. This one cylinder is much larger than the cylinders that actuate the hind pair of wheels; it is, we will say, thirty inches in diameter; is in fact so related in size to the pair of cylinders, that the steam that is exhausted from them, enters this one cylinder at, say, forty pounds pressure, while the boiler pressure that gives the steam to the first pair is 180 pounds. No steam can reach the large cylinder that has not passed through the two smaller ones. The reversing machinery of the two separate sets of engines are connected, so that reversing one reverses the other.

I have said that Mr. Webb has about fifty of these engines on his road. They are also being tried in France. The inventor claims for them, great economy over the old type of engines, of the best construction, and he is encouraged by his company to go on with the experiment. As yet they have not been tried here. I have seen the design of the system adapted to our construction of locomotive, that is to the bar frame engine. From this room I will say to Mr. Webb that what is now wanted to influence the introduction of the engines here is mainly some exact figures as to economy, not as compared to what other engines on his road have done, but the foot-pounds of work as measured on a dynamometer car (such as is used on the Pennsylvania road), per pound of coal consumed. I think Mr. Webb has already undertaken to furnish this information, and we wait its publication before accepting the invention as an improvement over our practice. Here he will meet with the prejudice against the crank axle. The crank made by Mr. Webb is not so objectionable as the old form of double crank axle. He makes a well-hammered straight axle, and then by hydraulic power bends it into a simple crank with easy curves from the straight part. All the early locomotive service on the Grand Trunk Railroad, of Canada, was inside-connected, with cranked axles, and the fearful breakage of these in the severe winter weather of Canada soon compelled the abandonment of the system. It does not follow that severe cold makes the axles more brittle, but it makes the road-bed less elastic and the hammering of the engine over the unyielding track is more severe on such pieces of machinery. I would like to comment very favorably upon many good points in the mechanical construction of Mr. Webb's engines; on the mode of making the fire-door holes, flanging both sheets out on an angle and riveting by power around the door hole, and swinging the door inward towards the fire in place of opening it out. He also dispenses with the bottom fire-box ring or "mud ring," and carries the water space in under the grate with an ash hole, like the fire-door, in the bottom of the box, and also one draft-hole low down on the vertical front face of the box.

A too hasty ramble through the shops of the London and Great Western road at Crewe was instructive, and there I had the pleasure of seeing a restored Trevethick high-pressure engine bearing date 1808, found by Mr. Webb, in a junk shop in London, and saved by him from the hammer of the scrap buyer. This engine will perhaps soon rest in the South Kensington Museum, along with the old engine of James Watt and the Headley Locomotive, and the other samples of the skill or ingenuity of the early mechanics.

I am told that there is now a movement on foot to build a monument to the memory of Trevethick, and to found scholarships in his name. I deposit with the Secretary, this evening, pamphlets fully explaining this matter. I cannot say that we can indorse the claim of Trevethick's admirers that he was the first inventor of the modern high pressure steam engine, as we believe that our own citizen, Oliver Evans preceded him by many years. In those days the interchange of thought between the two countries was not very easy, and the most favorable light in which we can view Trevethick's claim is that he re-invented the high pressure engine of Evans without taking the idea from him. One of the most interesting studies in mechanical progress that is possible in England and on the continent of Europe, is in the direction of typical machines, the progress of invention being manifest from the oldest machines being still in use. This is instructive, but does not accord with our ideas of progress. New machines that can do more and better work should drive the old crude contrivances into the scrap heap and into museums.

The museums are indeed rich in mechanical curiosities. In Edinburgh, Prof. Archer having charge of the Museum of Arts and Sciences, has a number of workmen in a shop equipped with good tools, making large sectional models of important machines. He had just finished a model of the Headley locomotive, and I now deposit in the Institute the printed description of this model as furnished by Prof. Archer. In Birmingham I was in the private workshop of James Watt. Mr. Geo. Tangye now lives in the Watt mansion, and keeps intact the place where the great mechanic spent the last working days of his life. The coals placed there by his own hands still rest in his little furnace, and his leather apron, the apron worn by James Watt, lies on his turning lathe.

In the transmission of power by means of belts, as compared to gearing, the practice in America has long been in advance of other countries. The wide first driving-belts, common in our mills, are not to be seen in England, but a change is now under way in that direction, and, as is often the case when a new system is pushed, ultra novelties are adopted. A system is now obtaining in England of using hemp ropes as first drivers. The fly-wheel of the engine is grooved, and from four to five ropes of about one and a half or two inches diameter each, are made to carry the power to the grooved driving pulleys on the line shaft. Five ropes running from one grooved pulley to another grooved pulley with no means of equalizing the strain on each cord of the system is not according to our ideas of good practice. One rope must do more work than the others and will give out the sooner. I incline to the belief that one rope even acts as a retardent to the others. They give each rope ten horse-power work to do, and say they work well; but they have had as yet too few years of use to test their durability. I have been told that the ropes last several years. Compare this life with that of a good double leather belt as first driver in use for thirty years and as good, almost, as new! This is no uncommon thing in our practice. We, in the design of machines, are inclined to make all we can out of the belt power, doing as little as possible with the gearing. It is no unusual thing abroad to see very heavy machines with trifling belt power. I have to show you, however, this evening some samples of very good belt made of links of leather, put together edgewise, like flat-linked chains. This form of belting is coming into very general use in England and in the Health Exhibition I had a chance to see the electrical machines, driven by this form of belt, as compared to ordinary leather belt and the merit of the link belt was manifest in the smooth running and freedom from vibration or wave. The belt is strong and very flexible. I have been told that its driving power is no greater than that of solid belts of the same weight, but at high speeds the adhesion is greater from the belt not being so apt to carry air between its surface and the pulley.

Many months spent in a new country is not sufficient to constitute any one an unerring critic of the engineering ability of the people, as the circumstances that govern the engineering thought, differ. We cannot use English facilities of handling our freight at the stations because the construction of our cars is not the same; and climatic considerations weigh with us. I lingered long in England, among the kind friends who were so willing to show me all they could of their methods and their work, and can say but little about those countries where the people, as some one says, "labor under the disadvantage of not speaking our language." The two great engineering societies of England, the Institution of Civil Engineers and the Institution of Mechanical Engineers accorded to your representative every opportunity to avail himself of what they could do in the way of showing the work and the men who have done the engineering work of that country. This was accorded as freely before he was elected a member of each, as after. To the many kind friends who made him feel at home in a foreign land, he sends his thanks. To you, who met many of the representatives from those countries at the time of the Centennial, he brings their messages of kindly greeting. Go where he would, even as far to the north as the railroads would take him in Sweden and Norway, he met those who remembered the kindness of Philadelphia in 1876, and who send to Philadelphians their best and warmest wishes.

TERRESTRIAL MAGNETISM AT PARIS.—The organization of regular magnetic observations at the Observatory of Pere St. Maur required the determination of the horizontal component in absolute measure. The method of Gauss was employed, under the direction of M. Massart, and from observations on 21 days, between Feb. 6 and June 27, inclusive, the mean value was found to be, in C. G. S. units, $H = 0{\cdot}19414 \pm 0{\cdot}00012$. — *Comptes Rendus*, Aug. 4, 1884. C.

STEAM BOILERS AS MAGAZINES OF EXPLOSIVE ENERGY.

By Prof. R. H. Thurston.

(Concluded from page 448.)

It should be noted that equations (A) and (B) give the quantity of energy available from unity of weight of the fluid, expanding from the initial temperature and pressure down to the temperature of steam of atmospheric pressure, in a non-condensing engine. The energy produced by that part of the operation represented by the expansion-line, in the boiler explosion, is obtained by deducting from this total the product of initial pressure, above the atmosphere, by the initial volume. Table I, of "available energy," represents the total; Table II, that of "stored" energy, the latter part. The former is the measure of the maximum work possible in a non-conducting cylinder; it represents a limit which may be approached, but which can never be reached in practice.

The energy of steam alone, as stored in the boiler, is given by column 10 of Table II.* It has been seen that it forms but a small and unimportant fraction of the total stored energy of the boiler. Table III exhibits the effect of this portion of the total energy, if considered as acting alone.

The study of this table is exceedingly interesting, if made with comparison of the figures already given, and with the facts stated above. It is seen that the heights of projection, by the action of steam alone, under the most favorable circumstances, are not only small, insignificant indeed, in comparison with the height due the total stored energy of the boiler, but are entirely too small to account for the terrific results of explosions frequently taking place. The figures of Table III are those for the stored energy of steam in the working boiler; they may be doubled, or even trebled, for cases of low water; they still remain, however, comparatively insignificant. While they may account for the explosion effects seen at the Sandy Hook experiment, it is by no means certain to the mind of the writer that they do so;

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* The figures here given should be substituted for those in Table II, which were uncorrected as above. The other columns remain practically unchanged.

it is very evident that they are not sufficient to account for the more violent explosions described. Either the energy stored in the water has been, in such cases, thus effective, or other sources of energy must be sought. These calculations, therefore, may, on the whole, be taken as strong evidence, if not absolute proof, of the correctness of the Colburn Theory of Steam Boiler Explosions.

TABLE III.—*Stored Energy in the Steam Space af Boilers.**

Type.	Energy total.	Stored in steam. Per pound of boiler.	Height of projection.	Initial velocity.
1 Plain cylinder......	676,693	271 ft. lbs.	271	132
2 Cornish....................................	709,310	42 "	42	52
3 Two-flue cylinder....................	2,377,351	351 "	351	150
4 Plain tubular............................	1,622,731	168 "	83	33
5 Locomotive...............................	1,483,896	76 "	76	69
6 " ....,......	2,135,802	85 "	85	74
7 "	1,766,447	86 "	86	74
8 "	1,302,431	107 "	107	33
9 Scotch marine.........................	1,462,430	54 "	54	59
10 " "	2,316,392	61 "	61	62
11 Flue and return tube............	1,570,517	28 "	28	42
12 " "	1,643,854	29 "	29	43
13 Water tube.............................	2,103,110	61 "	61	59
14 " "	3,513,830	79 "	79	71
15 " "	1,311,377	24 "	24	39

* Table III and related text were not ready at the time of printing the preceding part, and did not therefore appear in copies then distributed.

INFRA-RED RAYS AND BANDS.—H. Becquerel was led, by his examination of incandescent metallic vapors, to apply his methods to the solar spectrum. He publishes a table of wave lengths for the infra-red lines and bands, ranging between 760 and 1,880 millionths of a millimetre. His results show that the phosphorographic method, when the phosphorescent substances are suitably chosen, enables us to explore the lower regions of the spectrum as completely as the thermoscopic methods, and more thoroughly than chemical actions. The method has the advantage of giving instantaneous indications, and of presenting an image of the whole region which is explored.—*Comptes Rendus*, Sept. 1, 1884. C.

SOME PRINCIPLES AND RESULTS OF HARMONIC MOTION.*

By Pliny Earle Chase, LL.D.

"When two bodies, in relative motion, come into contact, pressure begins to act between them to prevent any parts of them from jointly occupying the same space. . . . Any force in a constant direction acting in any circumstances, for any time great or small, may be reckoned on the same principle; so that what we may call its whole amount during any time, or its '*time-integral,*' will measure, or be measured by, the whole momentum which it generates in the time in question." (Thomson and Tait, *Nat. Phil.*, i, sec. 294, 297.)

No relative motions can be more important, and no contact more complete, than those which exist between the all-pervading luminiferous æther and the sun. In the conversion of tangential luminous waves into spherical vibrations, gravity is acting in a constant direction toward the sun's centre. The amount of its activity upon each æthereal particle, μ, or its time-integral during each cyclical period, t, is measured by μgt. The study of the various correlations which flow from this integral involves the following considerations:

1. The principle of Galileo, that the total effort is equivalent to the effective sum of the causes which are operating. This is illustrated at sun's surface, which is the region of greatest energy in our system, by the cyclic equation, $\Sigma g = gt = v_\lambda$.

2. The equality of pressures or resistances to opposing forces, in all equilibrating tendencies. In consequence of this equality, every interruption or prevention of the free action of any force may be measured as a rate of change of momentum in the opposite sense.

3. The invariability of the sum of kinetic and potential energies.

4. The maximum of kinetic energy in all cyclical motions, at the point of the trajectory which is nearest to the centre of force, and the maximum of potential energy at the point which is most remote from

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* This paper has been written, in part, to meet a desire which has been expressed by some members of the Royal Astronomical Society for an introduction to the article on "Harmonic Motion in Stellar Systems" (this Journal, Nov., 1884). The author will feel under obligation to any readers of the Journal who will inform him of other points which need further elucidation.

that centre. At the origin of luminous radiation, where $\Sigma g = v_\lambda$, the reaction of gravitating resistance is all kinetic; after a half rotation it becomes all potential, but it is then combined with a new reaction which is all kinetic.

5. The evidences of local æthereal stress, which is operative in various forms of gravitating, thermal, electro-magnetic and chemical attraction and repulsion.

6. The indestructibility of energy, which requires, as Maxwell has stated, that energy must exist in the æther during the interval of its transfer from one body to another.

7. The strong reasons for believing that the media for luminous, gravitating, thermal, electro-magnetic and chemical interactions, occupying the same space and represented by the same cyclical velocities, are identical.

8. The counteraction of stress by obvious elasticity, as in a spring, or by probable intermolecular elasticity and orbital motion, as in the resistance of solids.

9. The principle of Fourier, that any complex periodic motion must be compounded of a definite number of simple harmonic motions, of definite periods, definite amplitudes and definite phases.

10. The application of "Laplace's coefficients," or spherical harmonic analysis, to the explanation of cyclical waves and vibrations in spherical elastic masses.

11. Cumulative and progressive undulating tendencies, resulting in complex harmonic motions of various kinds.

The evidences and consequences of harmonic motion in stellar systems flow simply and naturally from the two following important FACTS:

1. The fundamental velocity in the solar system is the velocity of light.

2. This is not a merely accidental and temporary coincidence, but according to the first proposition of "Newton's Principia," it must have existed and must continue to exist, during all past and future stages of solar condensation.

The first of these facts was discovered by investigating the tendencies to oscillatory nodal harmony in elastic media. It appears to be still regarded, by some persons, as merely curious and without important significance. This is, perhaps, because attention has been so often directed to the angular velocities in different orbits, which vary inversely as the $\frac{3}{2}$ power of the mean distance, that the synchronous variability of angular velocity with the inverse square of the radius, in all the particles of an expanding or contracting nebular nucleus, is forgotten or overlooked.

We find in our stellar system three stages of material aggregation: 1. A nucleus, probably consisting chiefly if not entirely of condensed gas, rotating in about 25·5 days. 2. An atmosphere of lighter gas, rotating synchronously with the nucleus and, therefore, extending no further than Kant's limit ($\rho_\kappa = 36{\cdot}35\rho_0$; ρ_0 being Sun's semi-diameter). 3. A luminiferous æther which, if infinitely elastic, may be of infinite extent, but which would reach if made homogeneous to 2210·74 times Earth's mean distance from the Sun.

If the Sun were homogeneous and unresisting, a particle would fall to its centre, from its surface or from any point within its surface, in 41·87 minutes, or in $\frac{1}{4}$ of the time of free revolution at the surface ($\frac{1}{4}$ of $2\pi\sqrt{\frac{r}{g}} = \frac{\pi}{2}\sqrt{\frac{r}{g}}$.) The relation of radial oscillation to orbital revolution is, therefore, that of simple harmonic motion. The velocity acquired by falling from the surface to the centre would be $\sqrt{gr}$, which is the same as would be acquired in falling from an infinite distance to $2r$, or from $2r$ to r, or in virtual fall through $\frac{1}{2}r$, or through one-half the length of a cycloidal pendulum which would oscillate synchronously with circular orbital revolution at r. It is also the velocity of wave propagation in a homogeneous elastic atmosphere of a depth equivalent to r.

At all points within the nucleus, the velocity acquired by fall to the centre would be proportional to the distance from the centre. Let us apply the principles which are here indicated to a stellar system like our own, with a nucleus so preponderating that its oscillatory tendencies are not materially modified by the perturbations of attendant planets or companion stars.

Within our solar nucleus all the tendencies to orbital revolution have been converted into constrained rotation, which shows a retardation by collision, subsidence-oscillations, etc., such that the velocity of every particle is only about $\frac{1}{219}$ as great as that of free and self-sustained revolution. The continual violent agitation of Sun's mass indicates the probability of synchronous radial and tangential oscillations, which are dependent upon simple harmonic motions. The measure of gravitating acceleration for the oscillatory unit of time being $\pi^2 l = \frac{3\pi^2 l_0}{2}$, ($l_0$ being the distance from the point of suspension to the centre of oscillation in a linear pendulum l), we have Sun's semi-diameter $(\rho_0) = \frac{3\pi^2}{2} l_0$ and the quotient of circular orbital velocity by equatorial velocity of rotation $(\sqrt{g_0 \rho_0} \div v_r) = \left(\frac{3\pi^2}{2}\right)^2 = 219{\cdot}17$.

The principle of conservation of areas requires that the angular velocity should vary inversely as the square of radius, without the nucleus as well as within it, provided we look merely at the orbit of any given mass or particle. It is only when we compare different extra-nucleal orbits in the same system, each of which has its own original force of projection, that we find angular velocities varying inversely as the $\frac{3}{2}$ power of the mean distance. If the nucleus is expanding or contracting, the Kantian radius, ρ_κ, should, accordingly, vary as the $\frac{4}{3}$ power of the nucleal radius, so that $\rho_\kappa = \left(\frac{3\pi^2}{2}\right)^{\frac{4}{3}} \rho_0 = 36{\cdot}35 \rho_0$.

The free undulatory velocity at ρ_0, both radially and tangentially, is $\sqrt{g_0 r_0}$. The mean harmonic radial velocity of rotary oscillation at the same point is $\frac{1}{\pi}$ of $\left(\frac{2}{3\pi^2}\right)^2 = \frac{1}{688{\cdot}54}$ as great, or $\left(\frac{1}{688{\cdot}54}\right)^2$ as great as the fundamental velocity, or the gravitating acceleration in the fundamental oscillatory unit of time.

As the idea of "fundamental velocity" will be new to many readers, it may be well to explain it. In whatever way g may act, whether by constant, successive, or undulatory, pressures, thrusts, or pulls, all of its results may be accounted for on the hypothesis of successive instantaneous impulses. The entire accelerating force, gt, is always exerted, but a portion is usually counteracted by opposing resistances or momenta. Suppose, for example, three bodies in a vacuum; A falling freely for a second, B suspended from a string between cycloidal arcs so that its centre of oscillation is $\frac{1}{\pi^2}$ of 32·08 feet from the point of suspension, C sliding on a frictionless plane in which $h : l :: 1 : \pi^2$. A will fall 16·04 feet, while B swings once and C slides 16·04 feet, falling through a height equivalent to one-half the length of the pendulum.

The choice of a second as the unit of time is altogether arbitrary. The desirability of a natural unit has often been felt and expressed. Maxwell suggested, as a suitable unit, the interval of some particular luminous wave-length. At the surface of a stellar nucleus, where gravity is a maximum, where the time of rotary oscillation can be linked with all possible times of revolution by simple formulas of harmonic vibration, and where a universal gravitating unit can be readily framed from the units of mass and density, the velocity, gt, which is indicated both by the gravitating and by the æthereal unit,* may properly be regarded as a fundamental velocity.

It is at present impossible to test the oscillatory velocities in remote stellar systems, but as the considerations on which they are based are universal, there are good grounds for believing that their influence is equally universal, so that $gt = v_\lambda$ at every stellar surface. In the solar system we find $t^\kappa = 1101227$ sec. = oscillatory unit of time = one-half solar rotation.

$g_\kappa = \pi^2 \rho_\kappa = \pi^2 \left(\frac{3\pi^2}{2}\right)^{\frac{4}{3}} \rho_0$ = unit of gravitating acceleration in unit of time at ρ_κ.

$g_0 = \pi^2 \left(\frac{3\pi^2}{2}\right)^4 \rho_0$ = unit of gravitating acceleration at ρ_0 in oscillatory unit of time = v_λ in oscillatory unit of time = solar modulus of light (= 185505 miles per sec.) = 185505 × 1101227 miles = $(688{\cdot}54)^2 \rho_0$.

$g_0 \div \pi \left(\frac{3\pi^2}{2}\right)^2 = \sqrt{g_0 \rho_0} = v_0$ = radial velocity acquired by falling from ρ_0 to the centre of a homogeneous nebular sphere = self-sustained velocity at surface of the sphere (= 269·42 miles per sec. at Sun's surface) = 269·42 × 1101227 miles in t_κ.

$\sqrt{g_0 \rho_0} \div \frac{\pi}{2} \left(\frac{3\pi^2}{2}\right)^2 = v_\rho$ = simple harmonic radial component of stellar equatorial velocity of rotation (= ·7826 miles per sec. for our Sun) = $2\rho_0 \div \pi$ in t_κ.

The cumulative influence of mean luminous undulation and solar action is shown by the proportions

$$v_\rho : v_0 :: v_0 : \tfrac{1}{2} v_\lambda.$$

$$v_\rho : v_\pi :: v_\pi : v_\lambda$$

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* The time of virtual fall through one-half homogeneous æthereal atmosphere.

In the second of these proportions v_π is parabolic velocity, or velocity acquired by infinite fall, at Sun's surface.

In studying planetary harmonies, regard should be paid to the following cyclical tendencies:

$t_1 \propto (d)^{\frac{1}{2}}$ in simple oscillation under a constant force.

$t_2 \propto d$ in cyclical motions which are immediately determined by luminous undulation, or by other constant velocities.

$t_3 \propto d^{\frac{3}{2}}$ in different orbits, under different original forces of projection but with the same central force.

$t_4 \propto d^2$ in a rotating and uniformly expanding or contracting nucleus.

If d in each instance is equivalent to the Kantian limit (ρ_κ) and if the mean density of the rotating mass is represented by δ,

$$t_1 \propto \left(\frac{1}{\delta}\right)^{\frac{1}{6}} \qquad t_3 \propto \left(\frac{1}{\delta}\right)^{\frac{1}{2}}$$

$$t_2 \propto \left(\frac{1}{\delta}\right)^{\frac{1}{3}} \qquad t_4 \propto \left(\frac{1}{\delta}\right)^{\frac{2}{3}}$$

If the mean density of Earth's Kantian rotation is taken as the unit, the corresponding reciprocals of density for Sun and for the several planets, except Neptune, are nearly as follows:

Sun	649·800	Mars	1·053
Mercury	1·207	Jupiter	·171
Venus	1·031	Saturn	·182
Earth	1·000	Uranus	·157

The influence of luminous undulation upon the actions and reactions between the chief centre of nucleation and the chief centre of condensation (Sun and Earth), seems to be indicated by the following tendencies:

t_2, in the conversion of circular motion into simple harmonic motion, $\propto \frac{2}{\pi} d$. d_3 representing such conversion, $\propto \left(\frac{2}{\pi}\right)^{\frac{2}{3}} d$.

The radius of mean condensation $(\frac{1}{2}\delta)$ is $2^{\frac{1}{3}}$ times the radius of actual condensation; $365{\cdot}256 \times \left(\frac{2}{\pi}\right)^{\frac{2}{3}} \div 2^{\frac{1}{3}} = 214{\cdot}54$. The apparent solar semidiameter which corresponds to this value is $961{\cdot}43''$, which differs by less than $\frac{1}{23}$ of 1 per cent. from the British Nautical Almanac estimate, $961{\cdot}82''$. Dr. Fuhg's estimate (*Astron. Nach.*, 2040), $961{\cdot}495''$, is still closer.

Tendencies to solar equatorial acceleration and polar retardation, such as are shown by the sun-spots, are indicated by the following approximations to the period of solar rotation :

$t_1 \propto \sqrt{d}$; $(36{\cdot}3514 \times 430891) \div (6{\cdot}6 \times 3962{\cdot}8) = (24{\cdot}472)^2$.

$t_2 \propto d$; $430891 \div (3962{\cdot}8 \times 3{\cdot}92295) = 27{\cdot}7174$.

$t_3 \propto \sqrt{\delta}$; $(36{\cdot}3514 \div 6{\cdot}6)^3 \times 3{\cdot}92295 = (25{\cdot}602)^2$.

$t_4 \propto d^2$; $(36{\cdot}3514 \div 6{\cdot}6)^2 = 30{\cdot}336$.

The secular influence of the chief centres of nucleation and nebulosity (Sun and Jupiter) on the chief centre of condensation (Earth), as well as the cyclical actions and reactions between Earth and Jupiter, are shown by the equation $\delta_5\, \rho_{3\beta} \div \delta_0\, \rho_{3a} = t_\beta \div t_a$.

In this equation δ_5, δ_0, are the mean Kantian densities of Jupiter, Sun ; $\rho_{3\beta}$, ρ_{3a}, the nearest secular approaches of Earth to Jupiter, Sun ; t_β, orbital period of Jupiter ; t_a, Kantian or rotational period of Earth. The secular eccentricity of Earth which satisfies this equation is ·06543. Stockwell's estimate is ·06774.

FLASHING TESTS FOR GUNPOWDER.—Prof. Chas. E. Munroe, U. S. N.A., cites descriptions of flashing tests, as follows : *Ordnance Instructions*, U.S.N., p. 345 ; Capt. Smith, R. A., in his *Hand-Book of the Manufacture and Proof of Gunpowder*, p. 83 ; Commander J. D. Marvin, in his *Objects and Resources of the Naval Experimental Battery*, p. 18 ; Col. Chabrier, in *Comptes Rendus*, lxxviii, 1138, and *Revue d' Artillerie*, iv, p. 396. Since the flashing test is the simplest, readiest, and in the hands of an expert, the best test for the incorporation of powder, and since it also fairly indicates the amount of deterioration which a powder has undergone during transportation and storage, it seemed desirable to seek some method by which the record could be made permanent. He believes that he has secured such a permanent record, by employing the paper which is used in the "Blue Print Process" of photography, and is easily procured in commerce. He prefers that which is issued by the Pennsylvania Railroad Company, for use among its operatives. His communication describes the various tests, and concludes with a satisfactory statement from Lieut. Commander W. M. Folger, U. S. N., commanding the Naval Experimental Battery.—*Jour. Amer. Chem. Soc.*, vol. 6, Jan. 1884. C.

ELEMENTARY PHYLLOTAXY.

By Pliny Earle Chase, LL.D.

I have shown* that the "numerics" of the chemical elements can be better represented by various phyllotactic divisors, than by Prout's law. Phyllotactic submultiples of the organic elements, C, H, O, N, give a mean residual ratio of ·05654, while Prout's law gives ·12007, the probable ratio of merely accidental residual being ·18394. This indicates comparative aggregate probabilities which are represented by the reciprocals of $\cdot05654^{65}$, $\cdot12007^{65}$, and $\cdot18394^{65}$, or by 1999×10^{30}, 1098×10^{9} and 1.

In the *Philosophical Magazine* for November, 1884, Dr. Edmund J. Mills gives additional evidences of phyllotactic influence. He represents all the elementary numerics, except that of hydrogen, by the equation,

$$y = p15 - 15(\cdot9375)^{x}.$$

This introduces the first five numbers of the phyllotactic series, 1, 2, 3, 5, 8, the equation being of the form

$$5 \times 3\,[p - (\overline{5 \times 3} \div \overline{2 \times 8})^{x}].$$

The sum of the infinite series which is represented by $15\,(\times\overline{5\times3}\div\overline{2 \times 8})^{x}$ is the product of the first five phyllotactic numbers, $1 \times 2 \times 3 \times 5 \times 8$. The fundamental ratio is of the form $(n \div \overline{n+1})$, thus representing cumulative harmonic rupturing tendencies of the same kind as are shown in the inter-stellar æthereal influence upon planetary positions. (*Jour. Frank. Inst.*, Nov., 1884, p. 349.)

An Error by Maxwell.—In his article on "Ether," in the Encyclopædia Britannica, Maxwell makes an inadvertent numerical transposition, giving 842·8, instead of 482·8, for the coefficient of rigidity, and deducing a consequent erroneous value for æther-density, $9{\cdot}36 \times 10^{-19}$, instead of $5{\cdot}36 \times 10^{-19}$. The error has been copied into some valuable text-books.—P. E. C.

Alpine Electromotors.—It is proposed to utilize the enormous water power of the Alps as a motive force for many of the electric railways in Switzerland. The first application of this kind will probably be from Saint-Moritz to Pontresina, a distance of about 9 kilometres.—*Lumiere Electr.*, May 31, 1884. C.

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[*] *Proc. Amer. Phil. Soc.*, xix, 591–601, xx, 431, etc.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

BY PROFESSOR EDWIN J. HOUSTON.

NO. 4.—DOLBEAR'S TELEPHONIC RESEARCHES.

As we have already intimated, Professor A. E. Dolbear, besides inventing the new system of electro-static telephony, has done much to give the present system of magneto-electric telephony its present commercial efficiency. His inventions in this direction cover a wide and varied field of research. We will describe some of the more interesting and valuable of these inventions.

It would appear that Dolbear was the inventor of the magneto-electric telephone. He was the first to point out the fact that the ordinary electro-magnets employed in the articulating telephone could be dispensed with, and permanent magnets used in their stead. He invented the magneto-electric telephone in September, 1876, and constructed his first magneto-electric telephone as early as October of the same year.

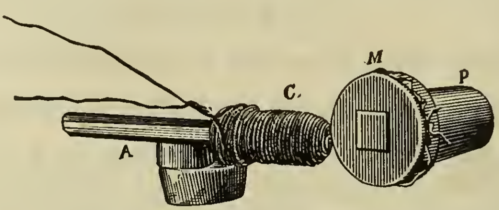

FIG. 1.—Dolbear's Original Magneto-Electric Telephone.

In Fig. 1 is shown the original Dolbear magneto-electric telephone from a photograph of the identical apparatus. As will be seen, it was somewhat crude in construction but was fairly efficient in operation and contained all the essentials of the magneto-electric instrument.

A permanent bar magnet *A*, had a coil of insulated wire *C*, wound around one end only. Its armature was formed of a rectangular piece of sheet-iron fastened to the middle of a thin rubber diaphragm, that was firmly stretched on the end of one of the hard-rubber tubes of an old opera glass. This form of apparatus was designed for use both as a transmitter and as a receiver, and was employed without a voltaic battery.

Crude as this instrument was, its invention marked a great advance in the art of telephony. Like many things that appear of the greatest simplicity when once originated, its successful operation could hardly have been confidently predicted. Indeed, we doubt whether most electricians would have believed that the magneto-electric currents thus generated by the voice would possess the requisite strength to reproduce the voice. It would scarcely have been considered probable that the resulting magnetic variations in the receiving instrument could produce such movements in the diaphragm as would permit it to reproduce audible, articulate speech. The scientific world was then, to a great extent, ignorant of the exceedingly small amount of motion requisite to produce audible sounds. It also lost sight of the very evident fact, that the comparatively great velocity of movement of the magnetic diaphragm, must necessarily result in the production of a proportionally large current in the coils of wire on the magnet pole.

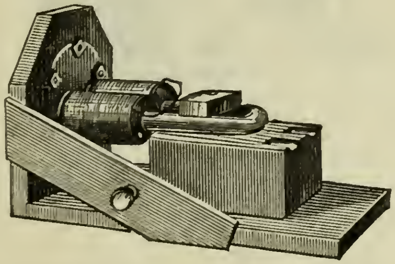

Fig. 2.—Dolbear's Magneto-Electric Telephone (Bi-polar),

Dolbear improved the magneto-electric telephone shown in Fig. 1, by an instrument that he constructed in December, 1876. This form of instrument is shown in Fig. 2, and consists of a horseshoe magnet of round steel, that is, of course, permanently magnetized. Bobbins of insulated wire are placed on the ends of the poles in the position shown. Fig. 2 is reproduced from a photograph of the instrument as actually made by Prof. Dolbear. It is interesting as showing a metallic diaphragm, bolted at its edges to the upright, wooden mouth-piece. The bobbins on this instrument were taken from an old telegraphic instrument. Dolbear employed his first metallic diaphragm in October, 1876, in an instrument used in connection with the apparatus shown in Fig. 1. His first metallic diaphragm consisted of a piece of sheet-iron that entirely covered the end of a wooden tube.

In Fig. 3 is shown an ingenious form of transmitter invented by Dolbear in 1878, and named by him the finger transmitter. It consists of an empty tomato-can, the metallic bottom of which is brought into good electrical contact with one end of an electric circuit by wrapping the wire around the bottom edge and soldering it thereto. If now the wire from the other terminal of the battery circuit be grasped in the hand, and the finger be held against the middle of the bottom of the can, as shown, any sound made into the open end of the can will vibrate its bottom and thus vary the strength of the battery circuit, by reason of the varying contact of the finger and the bottom of the can. If, therefore, any form of receiving instrument be introduced into the circuit, anything spoken into the open end will be distinctly heard in the receiving instrument.

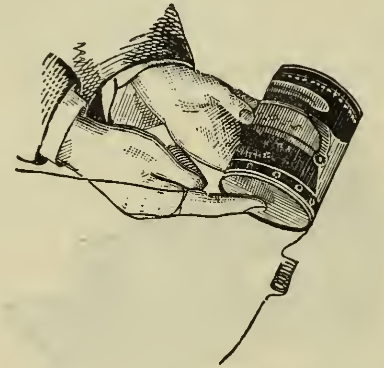

FIG. 3.—Dolbear's Finger Transmitter.

Since the resistance of the finger is high, it is necessary to employ from ten to twenty gravity cells in order to obtain satisfactory results.

This form of transmitter is dependent for its operation on the principle of the microphone transmitter, or in other words, it is a variable resistance transmitter. Though of comparatively little practical importance, it is interesting as illustrating the ease with which efficient telephone transmitters may be constructed; or how readily one could be devised for use in case of a sudden emergency.

In a previous article we spoke of Dolbear employing for a transmitting instrument a modified form of Reis transmitter. In Fig. 4, is shown a back view of one of these modified transmitters. A brass tongue, the end of which is tipped with a platinum wire is fastened to the inside of a wooden ring, so that the end of the platinum tip touches the middle of a vibrating diaphragm. The screw that may be seen passing through the cross bar, serves to regulate the pressure of the platinum tip upon the plate. The brass tongue has one of the terminals of a battery connected with it, and the metallic plate or diaphragm is connected with the other terminal. These wires are shown in the figure as passing through the handle.

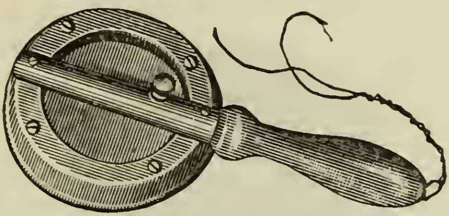

Fig. 4.—Dolbear's Modified Reis Transmitter.

This transmitter, which, it will be observed differs from the forms employed by Reis, mainly in the fact that the ordinary membraneous diaphragm is replaced by a metallic diaphragm, has been successfully employed by Prof. Dolbear to transmit intelligible, articulate speech between Boston and New York. When used for this purpose it was included in the circuit of 100 gravity battery cells, and the speech reproduced by the receiving instrument was so loud and distinct, that it was heard at a distance of ten feet from the receiver.

This transmitter is especially effective when included in the primary circuit of an induction coil. Without stopping here to discuss the peculiar advantages of the induction coil in telephony, it may be well to remark that the currents sent over the main line from the secondary coil are of the alternating character that characterize the magneto-electric currents.

Besides the modified Reis transmitter shown in connection with Fig. 4, Prof. Dolbear has invented a number of multiple transmitters; one of these is shown in Fig. 5.

In this form of transmitter four separate terminals are shown, so arranged that all of them may be placed in the same circuit, or each may have a separate circuit of its own, and thus be employed with one induction coil, like a single terminal one, "or with multiple points, each with its own circuit in an induction coil with multiple primaries, or with separate coils, or any combinations of these." In this form of transmitting instrument, Dolbear has arranged the vibrating plate horizontally as in Reis's second form of transmitter.

Dolbear has invented a quite distinct genus of telephone receivers to which he has given the general name of rotophones. This instrument, like Edison's motograph, operates by variations in friction. It is quite distinct, however, in the method of its operation, an electric current being caused to modify the magnetic friction of a body attached to the centre of an elastic diaphragm.

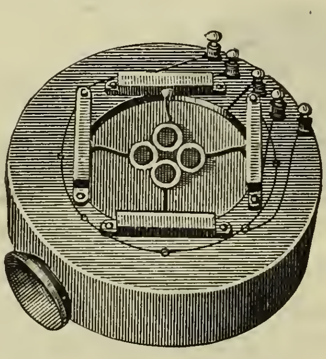

FIG. 5.—Dolbear's Multiple Transmitter.

In Edison's motograph, a diaphragm is set into vibration by the variations in the friction of a metal strip on a cylinder of chalk. The chalk cylinder is saturated with an electrolyzable substance and is rotated. The passage of an electric current between the metal and the chalk will cause the friction between these two surfaces to become less. If, therefore, the cylinder be rotated the friction will vary with variations in the current, and corresponding movements will be produced in a diaphragm that is connected with the metallic strip.

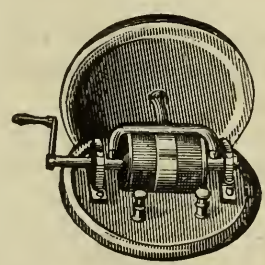

FIG. 6.—Dolbear's Rotophone.

Now Prof. Dolbear employing these variations in magnetic friction has constructed a distinct genus of receiving telephone, the principles of operation of which will be understood by reference to

Fig. 6. An electro-magnet, with a straight core, is provided with a handle so that the core can be readily rotated. A flat U-shaped armature is provided, the ends of which are permitted to rest on the ends of the core that project beyond the coil. In the middle of the U-shaped armature a short rod is secured at one end, the other end of which is attached to the centre of a vibrating plate of mica, or elastic metal. The explanation of its action is thus stated by Prof. Dolbear in a paper descriptive of the rotophone, that he read before the American Academy, on May 14, 1879. "When a current of electricity is made to traverse the coil, the core becomes a magnet and the armature is attracted to it; if the core be rotated, the adhesion of the armature will carry the middle of the diaphragm towards the magnet, and if the current be stopped, the elasticity of the plate will cause it to return to its original place. A vibrating current will thus set up corresponding vibrations in the diaphragm so long as the magnet turns."

Prof. Dolbear has produced some very simple and curious modifications of this form of telephone receiver. For example, if the end of the string of a common string telephone be tied to a nail, and the latter be placed on the pole of an electro-magnet that is in the circuit of a transmitting instrument, a person listening at the tube of the string telephone, will distinctly hear whatever is uttered into the transmitter, provided the nail is slowly drawn over the magnet pole. A motion of but two inches a minute will be sufficient in most cases.

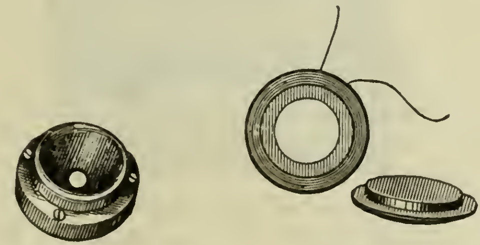

FIG. 7.—Early Forms of Dolbear's Static Telephones.

In Fig. 7, two of the early forms of Dolbear's static telephones are shown. One of these consists of two tin discs about two inches in diameter, separated from each other by a rubber ring about a quarter of an inch in breadth, thus forming a true air condenser. These were mounted in wooden cases, with an opening through the face for listening.

The form of static telephone shown in Fig. 7, to the right, consists of a circular plate of tin securely fastened to the bottom of a shallow box. Electric conduction, between the back and front disc is prevented by the use of a ring of paraffined paper. The front disc was formed of a disc of gilt paper, tightly stretched over a ring and connected to one of the terminals of an induction coil.

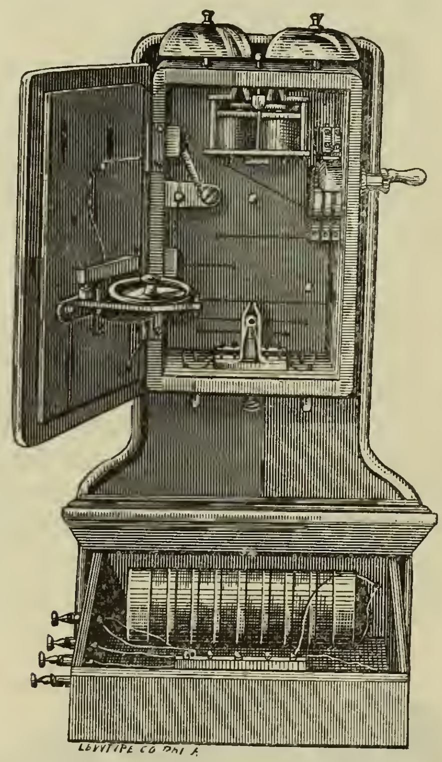

FIG. 8.—Dolbear's Secondary Ringers.

The two forms above described in connection with Fig. 7, were but a few of the numerous evident modifications of the same that were tried. Dolbear also made a telephone receiver, of a series of condensing discs. In one instance as many as fifty of these separate discs were used. As might have been expected, however, this modification was not productive of any good results.

The resistance of Dolbear's receivers is of course very great. One of them, he states, has a resistance of upwards of 10,000 megohms, while its capacity is about 2 or 3 ten-thousandths of a microfarad.

In Fig. 8 is shown Dolbear's arrangements for call bell, transmitter, etc. The handle, shown near the upper right corner of the figure, when turned rapidly makes and breaks the circuit of a number of battery cells that are placed in the lower part of the box. In this circuit is included the primary wire of an induction coil seen in the lower part of the figure. The ends of the secondary coil are connected to the main line, and the currents produced therein by induction, consequent on the making and breaking of the primary circuit, traverse the main circuit and ring the bell at the distant end of the line. By means of this exceedingly efficient form of apparatus, call bells are readily rung at distances of over 1,000 miles.

The ends of the secondary coil being connected with the main line the electrical charges are of course sent into the plates of the receiving instrument that is placed in a branch circuit between the terminals of the induction coil.

The ringing of the bell, therefore, at the same time charges the receiving instrument and thereby sensitizies it to its maximum, thus fitting it to act as a delicate receiver when removed from its hook.

The transmitting instrument is attached to the door of the box and is then enclosed when the door is shut. It consists of a shallow box with a modified Reis transmitter in which the platinum points ordinarily employed by Reis are replaced by carbon tips.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, November 25, 1884.

PRIVATE TELEPHONE.—John Burns, a Glasgow merchant, has united his office with his house, a distance of fifty-two kilometres, or over thirty miles, by a telephonic wire. In order to prevent disturbance from the induction of neighboring wires, he uses a return wire, the two wires being so arranged as to resemble the two threads of a twisted cord. Imagine, upon each arm-post, four positions at the four right angles of a square. The sending wire is attached to insulator 1 on the first post, 2 on the second, 3 on the third, 4 on the fourth, 1 on the fifth, and so on, forming a very elongated helix. The return wire is attached to insulator 4 on the first post (at the angle opposite to 1), 3 on the second, 1 on the third, 2 on the fourth, 4 on the fifth, etc., forming a helix parallel to that of the sending wire. In this way the effects of induction are neutralized in the two wires. The electric insulation is so perfect that neither the passage of trains nor telegraphic despatches in neighboring parallel wires produce any disturbance. —*Chron. Industr.*, May 25, 1884. C.

THE UTILIZATION OF NATURAL GAS.*

To the President and Members of the Engineers' Society of Western Pennsylvania:

GENTLEMEN.—Your committee appointed in January to examine into and report upon the utilization of natural gas, beg leave respectfully to submit the following report:

After prompt organization we have held a number of meetings, and have visited several prominent manufacturing establishments where natural gas is being used. We have examined into the methods of distributing and regulating the pressure in mains, and the question of municipal control.

We have from the outset taken counsel with the Board of Insurance Underwriters of Allegheny County.

We have to express our grateful acknowledgments to the following gentlemen for courtesy in affording us facilities for the prosecution of our work: President Ford, of the Pittsburg Plate Glass Works, Creighton Station, Pa.; Messrs. Atwood & McCaffrey, Messrs. Carnegie Bros. & Co., Mr. Howard Morton, Forward Avenue, East Liberty; Mr. Pew, of the Penn Fuel Company; Messrs. Spang, Chalfant & Co., Fuel Gas Co., all of Pittsburg.

It is now nearly twenty-five years since the first wells drilled into the sand and rocks of Venango County gave origin to the great and steadily increasing petroleum industry, but we have only recently begun to realize that with the petroleum is associated an invisible fuel, which by reason of its calorific power and the variety of its possible applications may yet assume a degree of commercial importance comparable to that of petroleum.

I. Natural gas from Western Pennsylvania is, in most cases, a mixture of more or less complex character. The few investigations published during the past few years tend to show that it is essentially composed of the hydro-carbons of the series known in chemistry as paraffins. In an accompanying table are enumerated some of the leading members of this series.

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* Report of a Committee of the Engineers' Society of Western Pennsylvania, presented May 21, 1884.

Table showing the properties of the chief gaseous elements of natural gas and including some of the heavier hydro-carbons.

Paraffins.	Condition.	Composition.		Specific Gravity of vapor.	Heat units yielded by 1 lb. in burning.	Cubic feet of air theoretically needed to burn 1 cubic foot of vapor.
		Per Cent. Hydrogen	Per Cent. Carbon.			
Marsh Gas......	Gas........................	25·04	74·96	0·5576	13·370	9·56
Ethane.....	Gas....................	20·05	79·95	1·043	12·469	16·74
Propane.........	Gas........................	18·22	81·78	1·522	12·145	23·92
Butane............	Gas, liquefies at 34° Fahr............	17·28	82·72	2·007	Not yet experimentally determined for the higher members.	31·10
Pentane..........	Liquid, boils at 100° Fahr............	16·71	83·29	2·49		38·28
Hexane..........	Liquid, boils at 158° Fahr............	16·32	83·68	2·97		45·45
Heptane.........	Liquid, boils at 210° Fahr............	16·04	83·96	3·46		52·63
Octane............	Liquid, boils at 255° Fahr............	15·83	84·17	3·94		59·80

From the table it is evident that the members differ in their relative proportions of carbon and hydrogen. The vapors of these hydrocarbons are heavier as the proportion of carbon is greater. The calorific values show the superiority of marsh gas, weight for weight, over all the others. The first three are odorless; among the others the odor is stronger in proportion as the amount of carbon is greater. A remarkable similarity of chemical properties is exhibited by all, and by reason of the strong attraction existing between them, the boiling point of a mixture is always found to be considerably higher than that of its most volatile constituent. They are theoretically the point of departure for the formation of a great number of useful compounds, such as alcohol, chloroform, acetic acid, and glycerine, but, on account of serious technical difficulties, due chiefly to their remarkable resistance to ordinary chemical reagents, (paraffin, parum and affinis), they have never yet been turned to practical account. They are not actively poisonous. It should be stated that many of these paraffins are known to exist in several different modifications, differing especially in boiling points. Hence the list of boiling points above given must be understood as merely including the temperatures at which the typical members of the paraffin series pass from the liquid to the vapor state. It will serve to show that what is a gas or vapor in summer may become a liquid in winter,

Table of Analyses of Natural Gas. (From Various Sources.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Constituents.	Petrolia, Canada.	West Bloomfield, N. Y.	Olean, N. Y.	Fredonia, N. Y.	Pioneer Run, Venango Co., Pa.	Burns' Well, near St. Joe., Butler Co., Pa.	Harvey Well, Butler Co., Pa.	Cherry Tree, Indiana Co., Pa.	Leechburg.	Creighton.	Penn Fuel Co.'s Well, Murraysville.	Fuel Gas Co.'s Well, Murraysville.	Roger's Gulch, Wirt Co., W. Va.	Gas from Marsh Ground.	Baku, on the Caspian Sea.	Gas occluded in Wigan Cannel Coal.	Blower in Coal Mine, South Wales.
Hydrogen	Chiefly marsh gas with ethane and some carbonic acid.	....	....	A mixture of marsh gas, ethane and butane.	Chiefly propane with small quantities of carbonic acid and nitrogen.	6·10	13·50	22·50	4·79	....	Marsh gas with a little carbonic acid.	19·56	Chiefly marsh gas with small quantities of nitrogen and 15·86 per cent. carbonic acid.	....	0·98	....	....
Marsh Gas		82·41	96·50			75·44	80·11	60·27	89·65	96·34		78·21		47·37	93·09	80·69	95·42
Ethane		....	....			18·12	5·72	6·80	4·39	....		....		....	....	4·75	....
Propane		....	....			trace	....	....	trace	....		....		....	....	....	....
Carbonic Acid		10·11	....			0·34	0·66	2·28	0·35	3·64		....		3·10	2·18	6·44	0·60
Carbonic Oxide		....	0·50			trace	trace	trace	0·26	Trace of heavy hydro-carbons.		....		....	....	....	....
Nitrogen		4·31	....			....	....	7·32	....			....		49·39	0·49	8·12	3·98
Oxygen		0·23	2·00			....	....	0·83	....			2·20		0·17	....	....	....
"Illuminating Hydro-carbons"		2·94	1·00			....	....	....	0·56			....		....	3·26	....	....
		100·00	100·00			100·00	99·99	100·00	100·00			100·00		100·03	100·00	100·00	100·00
Specific gravity		0·693	0·692			0·6148	0·5119		0·5580	0·5923	0·56						

1. Fouqué, "Comptes Rendus," lxvii, p. 1045.
2. H. Wurtz, "Am. Jour. Arts & Sci." (2) xlix, p. 336.
3. Robert Young.
4. Fouqué, "Comptes Rendus," lxvii, p. 1045.
5. " " " " "
6. S. P. Sadtler, Report L, 2d Geol. Sur. Pa., p. 153.
7. S. P. Sadtler, Report L, 3d Geol. Sur. Pa., p. 152.
8. S. P. Sadtler, Report L, 3d Geol. Sur. Pa., p. 153.
9. S. P. Sadtler, Report L, 3d Geol. Sur. Pa., p. 153.
10. F. C. Phillips.
11. Robert Young.
12. Rogers.
13. Fouqué, "Comptes Rendus," lxvii, p. 1045.
14. Bischof's "Chemical Geology," I. p. 730.
15. Bischof's "Chemical Geology," I, p. 730.
16. J. W. Thomas, London "Chem. Society's Journal," 1876, p. 793.
17. Same, 1875, p. 793.

In the lower sand rocks of the oil regions occur probably all the members of the series, the less volatile flowing as petroleum, and the more volatile existing in a state of compression ready to escape through every opening.

Natural gas is then a mixture of the most volatile of these hydro-carbons, carrying various quantities of the vapor of the less volatile compounds. The lightest member, marsh gas, (so called from its constant occurrence among the products of vegetable decay), is the chief element of the gas likely to be supplied to Pittsburgh. In addition to these, hydrogen, carbonic acid, carbonic oxide, oxygen, and nitrogen are found.

It is stated that $C_2 H_4$, ethelyne, and other hydro-carbons of the series known as olefines occur, but positive evidence upon this point is wanting, except in the extreme north end of the oil field. An accompanying table gives a general view of the composition of gas from a number of wells.

The table illustrates the predominence of marsh gas. Natural gas is usually a little more than one-half as heavy as air. The gas from Sheffield, Warren county, has a specific gravity of 0·45, while that from Pioneer Run, if the analysis of Fouqué is correct, must be about 1·5.

As the gas and oil sands all have a slight dip towards the southwest the gas in the southern part of the region is drawn from rock strata which are higher in the geological series than those yielding the gas in Northern Pennsylvania and New York State. If any attempt at a generalization may be made with the few data at disposal, it appears, therefore, that the deeper strata yield in general a gas of higher specific gravity and illuminating power.

Analytical data covering a greater area of gas-producing territory may in the future throw important light upon the interesting question of the origin of gas and oil. The theory which traces both to the sea-weeds of the ancient Devonian sea, which once covered Western Pennsylvania, has been very generally popular. Exhalations of combustible gas have been frequently met with in other countries, although nowhere in quantity comparable with the prodigious out-flow from the gas wells of Western Pennsylvania.

In the district Tsien-Luon-Tsing, in China, gas is obtained in large quantity from salt-well borings, and is used in boiling down the brine, and also for illuminating and heating purposes. ("*Comptes Rendus,* vol. XII, page 667). Some of these borings are 3,000 feet deep, and penetrate carboniferous strata, yielding gas under great pressure. Many openings have been made with the special view to utilizing the gas.

The escape of gas bubbles, which readily take fire and burn, is a common occurrence in strongly saline mineral springs. In the salt mines at Slatina, in Hungary, natural gas escaping from fissures has been utilized for illuminating the mines. This is an unusual instance in which the active component of the terrible enemy of the mines—fire-damp—has been made into a useful servant. Considerable volumes of combustible gas frequently issue from fissures in the well-known "mud-lumps," which form at the mouth of the Mississippi.

II. Wells drilled for natural gas, outside of the oil regions, are of recent date, with a few exceptions. The wells at New Cumberland, W. Va., have supplied gas for more than twenty years for the manufacture of bricks. The East Liverpool wells have been burning twenty-five years, and are still productive. At Beaver Falls, natural gas has been used for six years in a cutlery works, but lately the gas has failed, presumably on account of the wells becoming filled up with either paraffin wax in the pores of the rock, or with an incrustation of salts of lime and magnesia, as it is said they have never been cleaned out since they were drilled. At Erie so many wells have been drilled to the strata of gas rock that it has become partially exhausted. In the oil regions, a gas well was looked on rather as a curse than a blessing, and, as most of the wells produce gas as well as oil, and so many were drilled to the same sand or rock, it soon exhausted the supply.

Our city has the advantage of being able to tap three or four prolific gas belts or fields: The Butler County field, which supplies Spang, Chalfant & Co.; the Bull Creek, or Tarentum field, which struck gas at 1,147 feet depth, and supplies the Pittsburgh Plate Glass Company, Pennsylvania Salt Manufacturing Company, and will supply Richards & Hartly's and Chalinor & Taylor's new glass houses, and Godfrey & Clark's new paper mill. The Murraysville, or Turtle Creek and Lyon's Run field, which tapped the gas at 1,337 feet depth, and supplies the gas for the Acme Gas Company, used by the Edgar Thompson Steel Works; the Fuel Gas Company, which furnish the gas to the several mills and glass houses on the South Side; the Penn Fuel Company, which furnish the Union Iron Mills, Park Brother & Co. Limited, Wilson, Walker & Co., Hussey, Howe & Co., Shoenburger

& Co., and many other works in the same neighborhood on the Allegheny river. The belt or field in Washington County, in which the celebrated McGuigan well is found, the gas from which is being piped to the South Side. No doubt other prolific fields will be found to produce gas in the near future.

We have records of depths of different wells in different districts which we thought best not to include in this report.

If small wells are struck on the same belt as large ones, and are not sufficiently productive to be utilized, they should be plugged, as they drain the belt to no purpose. The more durable wells tap the gas-producing strata generally at a greater depth than one thousand feet.

It is a common opinion among those versed in the management of gas wells that the outflow is subject to a gradual diminution, tending ultimately to total extinction. Evidence of this is to be found in all parts of the gas territory, where gas wells have been long in use. In many localities, however, there is reason to think that the gradual falling off of the supply of a well, is due to the choking up of the pipe by a deposit of salt or paraffin, rather than to the failure of the original source. This is notably the case with the Freeport gas wells.

The following historical facts in regard to the wells drilled by Spang, Chalfant & Co., are of interest in this connection :

No. 1. Has been in use nine years, and is still a good well.

No. 2. Four years in use, still blowing, though with diminished force. Its location is three miles distant from any other gas belt.

No. 3. Yield insignificant.

No. 4. Pressure diminished from 1½ pounds to 0 in one week.

No. 5. Failed after four years' use.

No. 6. In use six years ; gradually failing.

No. 7. Failed after five years' use.

No. 8. Good yet ; drilled in 1883.

No. 9. Dry hole on Anderson farm ; struck quick-sand at depth of over 1,100 feet.

No. 10. Was a small well.

No. 11. A good well ; gas struck within the past few days.

These wells being all in Butler County, their partial failure may be due to close contiguity to the numerous oil wells of that district by which they have been drained.

These wells have been supplying the mills of Spang, Chalfant & Co. some years with varying success, being able to supply the entire plant at times, and then as the wells failed, and before others could be drilled, the gas supply was sometimes insufficient, and it was therefore either necessary to stop part of the machinery, or return to the use of coal.

III. The number of companies chartered to supply natural gas in Pennsylvania up to February 5, 1884, was 150, representing a capital stock of $2,160,580. Since that date, a large number of new charters have been granted.

IV. Natural gas next to hydrogen, is the most powerful of the gaseous fuels, and if properly applied, one of the most economical, as very nearly its theoretical heating power can be utilized in evaporating water.

It is used for almost all the purposes to which coal is applied, with one notable exception, viz.: for smelting ores in blast furnaces, and it is our belief that at no distant day it will be used for this, but not in the present style of furnace.

Being so free from all deleterious elements, notably sulphur, it makes better iron, steel and glass than coal fuel. It makes steam more regularly (as there is no opening of doors, and no blank spaces are left on the grate bars to let cold air in), and when properly arranged, regulates the steam pressure, leaving the man in charge nothing to do but to look after the water, and even that could be accomplished if one cared to trust to such a volatile water tender. Boilers will last longer, and there will be fewer explosions from unequal expansion and contraction, due to cold draughts of air being let in on hot plates.

Gas engines of large size can be built to be driven by natural gas, as in the case of the Otto, and other styles.

Table showing comparative effects of different gas fuels.

	Heat Units yielded by 1 Cubic Foot.	Number of Cubic Feet Needed to Evaporate 100 Pounds Water at 212 deg. F.
Hydrogen	183·1	293
Water Gas (from coke)	153·1	351
Blast Furnace Gas	51·8	1038
Carbonic Oxide	178·3	313
Marsh Gas	571·0	93·8

For domestic purposes a beautiful fire can be made, dust, ashes and coal carriage avoided; smoke, and the smoked ceilings and walls of Pittsburgh may become things of the past, yet if sold at prices now charged, *i. e.*, 50 cents per thousand cubic feet, it is much more costly than coal, especially if used in grates and stoves constructed for coal. The invention of burners for its more economical consumption in stoves must follow its general introduction.

As the introduction of natural gas has been of such recent date in this city, most of its users consume it in such a crude manner that they fail to get its best results, the difficulty being the expense of making the necessary changes in the burning. There is, however, one notable exception among the large consumers, namely the Union Iron Mills of Messrs Carnegie Bros. & Co., where it is being used with economy in Siemens' regenerative furnaces.

An experiment was made to ascertain the value of gas as a fuel in comparison with coal in generating steam, using a tubular boiler of 42 inches diameter, 10 feet long, with 4-inch tubes. It was first fired with selected Youghiogheny coal, broken to about 4-inch cubes, and the furnace was charged in a manner to obtain the best results possible with the stack which was attached to the boiler. Nine pounds of water evaporated to the pound of coal consumed was the best result obtained. The water was measured by two metres, one on the suction, the other on the discharge. The water was fed into a heater at a temperature of from 60° to 62°. The heater was placed in the flue leading from the boiler to the stack in both gas and coal experiments. In making the calculations the standard 76-pound bushel of the Pittsburgh district was used; 684 pounds of water were evaporated per bushel, which was 60·90 per cent. of the theoretical value of the coal. When gas was burned under the same boiler, but with a different furnace, and taking a pound of gas to be 23·5 cubic feet, the amount of water evaporated was found to be 20·31 pounds, or 83·40 of the theoretical heat units were utilized. The steam was under the atmospheric pressure, there being a large enough opening to prevent any back pressure: the combustion of both gas and coal was not hurried. It was found that the lower row of tubes could be plugged and the same amount of water could be evaporated with the coal, but with gas by closing all the tubes (on end next to stack) except enough to get rid of the products of combustion when the pressure on walls of furnace was three ounces and the fire forced to its best it was found that very nearly the same results could be obtained. Hence it was concluded that the most of the work was done on the shell of the boiler. Another experiment was made with the tubes plugged entirely, and a very small opening leading to stack and with an increased pressure on the furnace and of course a different style of burner; the results were nearly the same but the rivets and seams began to suffer, although only the same amount of gas was burned, but not in the same time. The gas required much more air to accomplish complete combustion per pound of fuel than coal. One singular fact was noticed, that is, when the products of combustion showed the smallest amount of carbonic oxide, the best results were not obtained. This was probably due to the fact that the increased heat due to the burning of the carbonic oxide to carbonic acid did not compensate for the loss occasioned by the amount of air that had to be let in to burn it and which air had to be heated to about 1500°. As the air, gas, and water were all accurately measured, the results were considered very nearly correct. Analysis of the gas in the escaping products of combustion were made quite often, only carbonic oxide and carbonic acid being determined.

Natural gas is being extensively used in heating boilers; in most cases by introducing a gas pipe with a row of small holes on its side, the fire space being closed up partly to check excessive draught.

No other data as to evaporative power are at the disposal of the committee, but it is apparent that in none of the boilers seen by us is the method of heating to be regarded as economical. A portion of gas taken from the flue of a 42″ × 24′ two-flue boiler consuming natural gas was found to contain nitrogen, 85·88, carbonic acid 6·16, and oxygen 7·96, showing that a great excess of air was passing up the chimney, notwithstanding that in this instance more than usual care was taken in the regulation of the draught.

So long as metres are not employed in measuring the volume of gas consumed in manufacturing establishments, it is scarcely probable that owners will study economy in its use. But with an increased demand for natural gas, particularly when its superior heating qualities, and low price, as compared with coal are understood, the officials of the supplying companies will doubtless take such action as will prevent the reckless waste of this valuable natural product. If, for instance, as it might be shown by cheap contrivances, easily applied, a factory could be better supplied with only one-third the present consumption of gas, the owners would certainly deem it no hardship if a meter was placed at their establishment, provided rates were not increased. In fact it is most probable that a perfect system of supply will reach many more consumers and with rates much lower than have heretofore been charged. At present the want of method by the companies, forbids as rapid a development of the gas supply as the public wants really require. Heretofore it seems that contracts have been made to supply the gas at rates only a trifle less than the cost of coal, but in the haste to declare dividends the companies seem to forget that by permitting its reckless waste by a few large consumers, they are crippling a resource which would yield better financial results through a more general distribution at more reasonable rates.

ILLUMINATING POWER.

V. The composition of the gas now being brought to Pittsburgh renders it improbable that it will compete with coal gas as an illuminant, until some specially suitable form of burner has been contrived. Pure marsh gas yields about one-half the light produced by coal gas.

Experiments made with a view to charging natural gas with the vapor of heavy hydrocarbons, have been thus far unsuccessful, the mixture tending to separate in the gas holder into layers of different composition.

USES.

VI. It has been attempted to apply natural gas to the conversion of iron into steel.

Experiments having in view the dephosphorization of iron through the agency of the hydrogen of natural gas have been made, but thus far the results have been very unsatisfactory. Imperfectly burned at a high temperature the gas deposits carbon in a form having a remarkable density. Upon this principle the manufacture of electric light carbons is now becoming an extensive industry in the hands of the McTighe Electric Light Company.

The tendency of the gas when under pressure is to absorb and carry off oil and grease, and leads to its being used for the cleansing of delicate fabrics.

The powerful reducing action of the gas upon metallic oxides at high temperatures may lead to its application to the smelting of metals upon a large scale.

The application of gas to glass making, on account of the purity of the fuel, has led to the production of superior glass; more rapid fusion is posible, and covered pots are found unnecessary.

VII. Pipes of various sizes and strengths have been tried and with different kinds of sockets or couplings. Standard weight wrought iron pipes, with fine and coarse threads, tapering threads and sockets, light pipe with the Converse joint, (which is a cast-iron socket caulked with lead, the same as ordinary cast-iron water pipe).

Lead rings have been used between the beveled ends of the pipe, in the regular socket. Pipes have been screwed together with fine threads, and the sockets caulked with copper wire. Cast-iron gas pipe with caulked lead joints has been used at Wellsburg, West Virginia, but on account of the high pressure of the gas, proved a failure, the gas leaking not only through the joints, but through the pores of the iron in many places.

The tapering socket, with pipe cut to match, seems to have the best record.

If standard wrought-iron pipe be used and laid in ditches below the frost line and care be taken in laying, no allowance need be made for expansion, for the flow of gas will keep the pipes at a fairly even temperature of not much over 45° Fahr., and no trouble from expansion or contraction need be feared. This statement, of course, does not apply to lines laid in cinder banks or where they are exposed to extreme changes in temperature due to proximity to furnaces, etc.

Light oil-well casing should not be used for pipe lines, because first, it is only ·1885 inches thick at its thickest part, and the thread (14 to the inch) reduces it ·061 inch leaving therefore, only ·1165 inch thickness, which is not sufficient. Again, some soils, and more especially cinder banks will rapidly corrode such thin pipes.

The Acme Gas Company use a ⅛-inch pipe of somewhat less than the standard weight, but still heavy enough to resist all ordinary pressure and strains.

The Fuel Gas Company have two lines of 5⅝ light casing, but they will never repeat this mistake, as they are about to lay two lines of standard weight pipes; all their city connections are made with standard weight pipes.

The Penn Fuel Company laid one line of 5⅝ *casing*, and one line of 8-inch *pipe*. Connections to mills are made with standard pipes, but it is to be regretted that this company laid any casing inside the city limits.

The varying requirements of a large iron works will render it desirable to be able at all times to control an unlimited volume of gas supported by high pressure.

In private dwellings the danger from explosions due to leaks in the pipes would be enormously increased by a pressure much exceeding that of ordinary coal gas in the service mains. In the opinion of the committee a pressure of over 6″ water pressure should be forbidden by law in pipes leading to dwellings.

Table showing comparative inflammability of natural gas and coal gas.

Mixture of Natural Gas and Air.		Effects.	Mixture of Allegheny City Coal Gas and Air.		Effects.
Gas.	Air.		Gas.	Air.	
1 volume.	4 volumes.	Burns feebly.	1 volume.	4 volumes.	Burns feebly.
1 "	6 "	Burns slowly.	1 "	6 "	*Explodes.*
1 "	7 "	Burns slowly.	1 "	7 "	Burns explosively.
1 "	8 "	Burns rapidly.	1 "	8 "	" "
1 "	9 "	Burns explosively.	1 "	9 "	" "
1 "	10 "	*Explodes.*	1 "	10 "	Burns explosively—less rapid.
1 "	12 "	Burns somewhat explosively.	1 "	12 "	Flashes.
1 "	13½ "	Burns quietly.	1 "	13½ "	No flash.
1 "	15 "	Flashes, but flame dies out.	1 "	15 "	"
1 "	16 "	Very feeble flash.	1 "	16 "	"

The importance of having the high pressure mains, as they enter the city suburbs, subjected to careful tests, and the mode of laying such pipes under municipal control, cannot be over estimated.

We are convinced that most scrupulous care is being bestowed, both by prominent manufacturers, in the construction of pipes and valves, and by some of the gas companies, in the selection of material.

The necessity for a reduction of the pressure, which is often 75 or 100 pounds per square inch as the gas comes from the well, to an amount not exceeding 5 inches water pressure in the street mains, renders the selection of regulating valves for accomplishing this purpose of great importance. The regulators proposed are of two classes.

1. *Valves.*—Among the best known is the Luther valve, by which it is proposed to reduce the high pressure in the mains leading from the well to an amount suited to the purpose to which the gas is to be applied, and to preserve constantly this lower pressure.

From what the committee have seen in the use of valves, we believe we are justified in the statement that not one has yet been suggested which will satisfactorily answer the purpose.

2. *Tank Governor.*—This is undoubtedly the best form of regulator which the committee has seen tested. It is similar in principle to the gasometers or holders employed at all the large gas works.

EXPLOSIBILITY.

VIII. The fact that natural gas if mixed with air will explode on contact with fire, and is in effect the dreaded fire damp of the coal mines is no argument against its introduction and general use under due precautions.

To those who understand its character, it is wholly unnecessary to state that the qualities which render it explosive when mixed with excess of air are the very ones which render it valuable as a producer of light and heat.

Taking the gas from Creighton Station, Western Pennsylvania, as approximately representing in composition the gas now being used in the city, the following trials were made with a view to ascertaining the limits of its inflammability.

Different mixtures of measured quantities of natural gas and air were prepared, and also mixtures in the same proportions of coal gas and air. The effect was noted when a coal gas flame was plunged into each. From these results we concluded that in a room filled with air containing $\frac{1}{10}$th to $\frac{1}{12}$th gas the danger would be one of explosion; above or below these limits, there would be danger of fire, but not of explosion.

A natural gas charged with the higher members of the series of paraffins (see Table page 49) would flash or explode when diluted with a still larger proportion of air. On the other hand if the air in a room contains $\frac{1}{6}$th or $\frac{1}{7}$th coal gas, contact with flame would cause explosion, while with an admixture of $\frac{1}{10}$th or $\frac{1}{11}$th of coal gas, there would be danger of fire, but not of explosion; as will be seen as regards safety there is a difference in favor of coal gas.

As coal gas is richer in free hydrogen, the most easily inflammable of all gases, its temperature of ignition may be assumed to be somewhat lower. The well-known property of coal gas, of rendering a mass of spongy Pt. or Pd. incandescent, is found to be generally wanting in natural gas.

Accurate experiments (*Bulletin de la Société Chimique*, 1883, page 2, Mallard & LeChatelier) have shown that a mixture of O. and H. ignites at 552°C. while a mixture of Marsh gas and O. ignites at a temperature between 600° and 660°C. A calculation shows that a cubic foot of natural gas mixed with 9·2 cubic feet of air, and fired, will produce an expansion to 91 feet. A cubic foot of coal gas mixed with 6½ cubic feet of air will, on explosion expand to 73·3 cubic feet. It has been found that a flash travels in an explosive mixture of natural gas and air at a rate considerably exceeding 18′ per second in a 2″ pipe.

Natural gas brings with it from the well the minute quantities of heavier liquid or solid hydrocarbons which are carried along in the form of vapor or spray by the force and velocity of the gas under high pressure, and impart to it a strong and characteristic smell.

A peculiar substance resembling butter is often taken from the mains bringing the Murraysville gas to the city. A specimen of this substance was found to contain common salt, water, small quantities of lime and magnesia salts, coarse sand and a considerable quantity of solid paraffin all blown into a kind of light froth.

The odor of the gas in the mains appears to be dependent upon these traces of condensible hydrocarbons, for if kept in a closed vessel for a few days, the gas becomes absolutely odorless. The odor will therefore in all probability diminish more and more as it is carried away from the wells, or from the high pressure mains. This may explain the contradictory statements upon this point which have found circulation.

It has been found that air containing 10 per cent. of Murraysville gas (fresh from the high pressure mains) has a decided odor; this is also true of Freeport and Creighton gas, but the same gas after standing in an air-tight glass for 24 hours had lost every trace of odor. Owing to their minute quantities and rapid condensation, these heavier hydrocarbons are not easily accounted for in an analysis.

Air containing 2 per cent. of Allegheny City coal gas has been found to possess a decided odor.

IX. The velocity of the gas depends largely on the amount of friction it has to overcome, as well as the initial pressure it has in coming from the well. A well which with its conducting pipes indicated pressure of 3¼ ounces of water at the mouth took just 4¼ minutes for the gas to traverse the 16,000 feet of pipe, which was then connected on, the pressure running up to 15 pounds at the well, due to the increased resistance in the friction of the pipe. The following experiment was also made. Gas was turned into the pipe with an initial pressure of 90 pounds per square inch. It took just 2¼ minutes for it to traverse the 16,000 feet of pipe.

Natural gas pipes should be laid without any right angled elbows, or other fittings of the kind; changed direction in the line should be made by bending the pipes, and no bend should have a radius of less than 48 inches for a 6-inch pipe, or eight times the diameter of the pipe.

Gas from a well having a pressure of 20 ounces had a velocity oı 23,400 feet per minute; a rubber ball was driven through three miles of a 5⅝ casing pipe in 2½ minutes.

When gas is blowing freely from the mouth of a well, the pressure has not been found in any case to reach 2 pounds per square inch.

Statements in regard to higher pressures than this are probably in error.

The gas as it issues from the wells has a temperature of 42° to 45° Fahr.

At the moment of release from the well the volume no doubt undergoes a very considerable expansion, resulting in a lowering of the temperature.

This absorption of heat due to expansion may perhaps explain the fact that blocks of ice are often seen to be thrown from the stand pipes while the gas is burning with a powerful flame.

The temperature has been found to be 45° in several of the mains in Pittsburgh.

X. At the time of the appointment of this committee, the prominent legal question of interest to natural gas companies was the definition of their rights to lay their pipes in the city streets, and as corrollary to this, the responsibility resulting from explosions or other accidents due to the use or presence of the gas. But recently a more important question has been brought forward by the decision of the local court that but one natural gas company under the law of 1874, is authorized to supply gas to consumers in this city.

As the law of 1874 is so frequently referred to in the newspapers, it may be useful to introduce it here for the benefit of readers who may not have ready access to a law library.

LAWS OF PENNSYLVANIA.

Act approved 29th of April, 1874, relating to water, gas, light and heat companies.

*1. Companies incorporated under the provisions of this statute for the supply of water to the public, or for the manufacture and supply of gas, or the supply of light or heat to the public by any other means, shall, unless otherwise provided by this act, from the date of the letters patent creating the same, have the powers and be governed, managed and controlled as follows:

Clause 1. *Gas, heat, light—powers of companies.*

2. Where any such company shall be incorporated as a gas company, or company for the supply of heat and light to the public, it shall have authority to supply with gas light the borough, town, city or district where it may be located, and such persons, partnerships and corporations residing therein, or adjacent thereto, as may desire the same at such price as may be agreed upon, and also to make, erect and maintain therein the necessary buildings, machinery and apparatus for manufacturing gas, heat or light from coal or other material and distributing the same with the right to enter upon any public street, lane, alley, or highway, for the purpose of laying down pipes, altering, inspecting and repairing the same, doing as little damage to said streets, lanes, alleys and highways.

3. And impairing the free use thereof as little as possible, and subject to such regulations as the councils of said borough, town, city or district may adopt in regard to grades, or for the protection and convenience of public travel over the same.

When the act of 1874 was passed, electric lighting was in its infancy, and it has been suggested that in deference to the promises of scientific men regarding its then future, that the terms of the act were purposely made so diffuse as to cover its possibilities—as instance, "The supply of gas, or the supply of light or heat to the public *by any other means.*"

This vagueness and want of supplementing legislation is a source of evil in various ways, and it is the opinion of the well-informed, that as the knowledge of electric lighting and of natural gas is *now* better understood, there is an urgent demand for additional legislation.

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* 1. Act 29th April, 1874, 34 P. L. 93.

2. Id.

3. In Bloomfield, etc. Gas Light Company *vs.* Calkins, 62 N. Y. 386.

1. Thomps & Co., 541; It was held that gas pipes could not be laid under country highways without compensating the owners of the fee. See supra. p. 56, N. 2, Dillon *vs.* Gas Light Co., 1 McArthur, 626.

There can be no doubt about the fact that the intention of the lawgivers, was to encourage both the electrician and the gas man, but the wants of the two interests are so different that only confusion and trouble will attend their affairs, until their rights and privileges are separately, and distinctly defined, and this it is reasonable to believe could be much more effectually accomplished by new legislation, than by awaiting decisions based upon such fundamentally defective laws, as that of 1874.

Under the law as understood by this committee, natural gas companies have the right to lay their pipes in the streets of towns and cities, with precisely the same privileges as coal gas companies, so far as such rights extend. But this does not prevent cities from passing laws based upon "reasonable grounds" ordaining the mode of laying the pipes as far as the language of the act cited allows as regards grades or for the protection and convenience of public travel over the same.

In regard to the question of the right of the city to restrict the gas companies, as to pressure in, and size and strength of pipes, etc., a difference of opinion exists, but under the head of "police regulations" it is believed by the committee that any insufficiency of strength in the pipes, or defective workmanship in the joints which might cause explosions, a city can in its charter find grounds for interference, and protect itself by the enforcement of appropriate legislation. But from the extent to which even this apparently wise and proper proposition has been debated, it is made clear that further action is demanded by the legislature. It does not, of course, comport with the character of this paper, even if the committee felt able to do so, to attempt to criticise the recent decision of the court, which is generally construed to grant one company, to the exclusion of all others, the privilege of supplying the city of Pittsburgh with natural gas.

Natural gas had been used under the boilers of engines at wells in the northern oil fields before the passage of the act of 1874, and to some extent it had been introduced into dwellings for domestic consumption, but it was then considered a waste product, which any one could dispose of by sale or gift, as could be done with any natural product, such as coal, limestone, or other minerals. It simply flows from the ground, with no process of manufacture involved in its formation, and no patentable form of composition, force or capability. It would, therefore, be strange indeed if our legislators intended natural gas to come within the scope of statutes governing the organization and specifying the privileges of manufacturing companies.

If the Engineers' Society of Western Pennsylvania were called upon to suggest on what points in connection with the subject of natural gas, legislation was desired, this committee would not hesitate to recommend for consideration, as follows:

First.—That a State Inspector of gas and artesian wells, and natural gas companies be appointed by the Governor, among whose duties we would specify: To report to the proper authorities, after due notice, any waste or extravagant use of natural gas, either at the wells or elsewhere, and that all natural gas companies be required to report to him the details of their operations, force and flow of the gas, and that all arrangements for its control at the wells, or in the pipes to a city, or borough line be under his general supervision. His office being compelled to keep up the records, and to report annually, with the aid of statistics and plans, the state of the natural gas supply and demand.

Second.—That in cities or towns, companies desiring to supply either manufacturers or domestic consumers with natural gas, may, with the consent of the councils thereof, and under the direction of the city or borough engineer, lay their pipes through or along any street, lane or alley, but no city or borough to have the right to give any exclusive privileges to any one gas company.

Awaiting the action of the State Legislature on the general matters which it might be expedient for that honorable body to consider, such as we have outlined above, your committee feel that they might be considered derelict in duty if they did not advise and propose, at least some measures which might be exercised by individual consumers of natural gas, tending both to security, as regards the dangers of fires and explosions, as well as to economy in its use.

We therefore would propose for the consideration of companies and individuals interested, the following:

First.—That the distributing mains for domestic consumption of natural gas be of size amply sufficient to conduct gas to dwellings with at no time or place a pressure exceeding 5½ inches (water pressure). This pressure can be guaranteed to be uniform, certainly never in excess, by a properly constructed form of tank governor.

Second.—Every domestic consumer of natural gas should see to it that an automatic cut-off valve be placed on his service pipe, so arranged in case the supply from the tank governor should from any cause fail, that his valve would immediately close the pipe conducting to his premises, and requiring personal attention to restore the pressure when it again returns through the main. The committee believe that such automatic valves can be provided.

Third.—No cast-iron fittings, or parts of fittings of cast, or any coarse-grained or inferior metal, should be allowed in private houses. Carefully selected wrought-iron pipes, with brass or malleable iron fittings should alone be adopted. The great object of care being to prevent the possibility of leaks.

Fourth.—Special care should be taken to see that the street cut-off, or valve, is so boxed or tubed as to permit free outlet to the air of any gas escaping from a leaky main which may follow along the branch pipe from the street. The work of trenching to and tapping gas mains should be done when the frost is out of the ground, and the soil next the pipes in such trenches should be clay, well wetted and puddled.

Fifth.—In the case of fires under boilers, in ranges, fire-places, stoves, etc., consumers of natural gas have, for the most part, entirely disregarded its laws of combustion in not using the proper appliances for the admixture of air with the gas jets. In many instances, even among wholesale consumers of this fuel, it can be demonstrated that with the use of improved mixers the same quantity of heat as is now developed, can be produced from one-third the volume of gas.

Sixth.—The feed valves to fires, and all burners where natural gas is used in private houses should be securely placed so far above the floors as to be out of the way of children and where they could not be accidentally turned on. To this end valve stems with movable socket handles are of advantage.

Seventh.—All gas pipes laid from service mains should be thoroughly tested for leakage before being accepted as in working order.

Eighth.—Where natural gas is sold either entirely or as a component part of illuminating gas its candle power should be guaranteed to be of a satisfactory amount.

Respectfully submitted,

T. P. ROBERTS, F. C. PHILLIPS,
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N. M. MCDOWELL,
Committee on Natural Gas.

ABSTRACTS OF REPORTS

OF THE BOARD OF EXAMINERS, INTERNATIONAL ELECTRICAL EXHIBITION OF THE FRANKLIN INSTITUTE.

[*Section No. 21.—Fire and Burglar Alarms and Annunciators.*]

EXHIBIT OF THE WESTERN ELECTRIC COMPANY.

The Hotel Fire Alarm and Room Call, exhibited by this company, is designed for the following purposes: When a call is received in the office by means of the annunciator, the clerk, by pressing one of the push buttons, can signify to the guest that the call has been received and will be attended to. Should the clerk desire to ascertain whether a guest is in his room, he can press on the proper button of the room call, and the guest, by pressing upon the button in his room, can signify that he is in. The room call can also be used to call the guests at any time desired; when employed for that purpose, the bell being kept ringing until the guest announces that he is both awake and up, by signaling back to the annunciator, causing the bell in the office to ring and his drop to fall. In case of a fire, by moving a switch, a crank is set in motion and rollers upon the two ends, by pressing upon the push buttons successively, ring the bell in every room.

The chief advantage claimed for this system is that it requires only the same battery as is in ordinary use for the hotel call, and it is therefore subjected to daily tests; but where a large battery is required for the fire alarm, there is a liability that, in time of a fire, from being seldom used, it will be found out of order. While there is quite a similarity in hotel annunciators, in this one the arrangements are novel and the mechanism simple in its construction, so as not to be easily disarranged.

In the Burglar Alarm Annunciator, the indications are made by means of the needle annunciator. By the action of suitably arranged switches it is possible to connect to or disconnect from the alarm, any part of the house, at pleasure; the annunciator and bell can be connected to the alarm if desired, or the annunciator can be connected and the bell not connected, thus giving a silent alarm; or to show whether the strength of the battery is sufficient to work the alarm, it can be connected with the bell alone.

By the system of "Continuous Ringing," the bell rings whenever an opening is made, not only as long as the opening remains but until attention is called to the alarm and the ringing stopped by means of the restoring apparatus. By means of a switch on each machine, the "Continuous Ringing" system can be used, or not, at pleasure.

The chief advantage claimed for the Williams Mechanical Gong is that it requires but a very slight electrical current to release the mechanism, and the hammer being near the centre of the shaft on which it swings, is easily set in motion, so that as it approaches the gong, the centrifugal force carries it into position.

For the Haskins Turtle Gong it is claimed that the pivoting of the armature is such that a very slight electrical current will be sufficient to actuate it. With this is combined the advantage of economy of space.

EXHIBIT OF THE NOVELTY ELECTRIC COMPANY.

The Novelty Electric Company exhibit the following Fire and Burglar Alarm systems:

The fire alarm exhibited was patented by Mr. Ahearn, of Ahearn & Soper, Toronto, Canada, and is designed as a cheap and economical system for small towns. Signal boxes are located at convenient points: these boxes are in electrical circuit with Bell Electro-Magnetos which are designed to be placed in engine houses, stores and private residences. The operation is simple and is as follows: The opening of the signal box door releases a weight, which, dropping, causes an armature to revolve between permanent magnets, which are similar in construction to the magnets and armature of the Bell magneto: this gives an effect the same as turning the crank of a magneto. On the spindle or the armature, or connected with it, is a small circular circuit breaker, which automatically signals the number of the station from which the signal has been sent upon all the bells with which it may be connected.

The burglar alarms exhibited were patented by D. Rosseau, of New York, and J. D. Lazelle, of New York, and contain the following important features: In addition to the alarm system, they have an attachment by which every door and window that is in circuit can be tested without the noise and annoyance of the bell ringing; this attachment is called a "silent tester." In the case there is also a clock which, besides being an ornamental time piece, automatically and at any hour desired, opens all or any part of the house, and at the same time rings an alarm for the purpose of calling the occupants of a certain room.

Burglar Alarm, No. 2, has all of the above attachments, with additional attachments to awaken different servants, guests and household at different hours.

Burglar Alarm No. 3, in addition to the attachments of No. 1, has the advantage of a gas connection, which works in conjunction with indicators or drops, so that in case a burglar opens a door or window, he not only rings the bell and drops an indicator, but also lights the gas and reveals his exact position.

Burglar Alarm No. 4, merely communicates an alarm without giving any indications from what particular point it comes. In order to locate the point of alarm the switches must be turned on the face of the alarm, when the correct one will stop the ringing of the bell. The annunciators are of the shuttle-drop kind, not complicated nor easily put out of order, and are claimed to be effective.

APPLEGATE'S ELECTRIC FLOOR-MAT ALARM.

This system comprises essentially an electric alarm bell, a mat-carrying circuit, and closing and breaking devices, so that when the mat is subjected to pressure the alarm will be sounded. The mat consists of narrow strips of wood connected to a fabric backing, and on the strip side of the mat is a series of springs which support the mat, there being two separate wires and the springs being securely connected to each wire. When the mat is stepped upon these springs are compressed, contacts are made, and a current is sent through the connecting wires (which are embedded or grooved in the wood) to the bell electro-magnet, so as to sound an alarm. The bell has a switch or lever on the frame, by means of which, when moved, the vibrating adjustments are displaced and the current ceases to flow through the armature spring or circuit breaker, then passes directly through the magnet, and upon the movement of this switch or side lever, it greatly lengthens the stroke of the armature, which is essential when a single stroke only is desired. The same lever that lengthens the stroke switches the current directly through the magnet closing the circuit, attracting and holding the armature. The reverse movement of the lever readjusts the bell as a complete vibrator with a short stroke.

There is also a further improvement, "automatic," in the form of a ratchet wheel which revolves by the movement of the armature by means of a pawl, the wheel revolving upon a projection from the bell frame. The wheel has a pin, or pins, inserted and properly insulated from it. As the armature vibrates, the wheel revolves and one of the projecting pins comes in contact with two delicate springs sending the current directly through the magnet and holding the armature, acting automatically and giving a short sound of the alarm with the circuit still closed at the mat or other circuit-closing devices. When the circuit is broken at the mat it is also broken at the two small springs on the bell ready to repeat the short alarm upon closing the circuit, thereby preventing an annoyance while the distant points may be connected.

A padding is used, in connection with the mat or matting, comprised of four thicknesses of paper, glued together, known as carpet padding pulp paper. Each of the strips of different width; thus, by laying it at the outer edges, graduating the carpet and hiding the mat, and, in addition to the finish, preventing the mat from cutting the carpet or other covering.

The mat exhibited is intended for use on an open circuit, but can be used also on closed circuits.

The advantages claimed for this system are security, portability, cheapness and convenience. The mats may be placed beneath the carpet and the wires entirely concealed so that the burglar has no chance of rendering the device inoperative by cutting the wires, while a few pieces of the matting placed in different portions of the house would provide ample protection. The mat alarm affords the same protection, whether the doors or windows are closed or open, and therefore interferes in no way with the proper ventilation of the house. The system is available as a call for stores, offices, banks, etc., as well as for a burglar alarm. As the mat can be put down and taken up without trouble, and as the wiring is very simple, it can be readily transferred from one house to another. We append a copy of the patents which explain the accompanying diagrams.*

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* Here follow copies of the drawings and specifications filed in the following patents: 195,074, September 11, 1877; 240,939, May 3, 1881, which the committee does not deem it necessary to re-publish.

EXHIBIT OF THE AMERICAN DISTRICT TELEGRAPH COMPANY.

The District Call system may be described as follows: A box contains a clock-work, which, when wound up, by the turning of a crank or handle on the outside of the box revolves a circuit-breaking wheel upon the periphery of which rests a connecting spring. When the crank or handle is placed at the word "messenger" and released, the revolution of the circuit wheel causes the connecting spring to drop into slotted or open spaces and breaks the main circuit and the signal of the box, thus arranged is received at the district or central office upon a relay, the back action of the armature of which closes a local circuit acting upon a bell and register and recording the signal. When the crank is placed at the word "police" and released, the circuit wheel makes two revolutions causing two registrations of the signal.

The several calls for which the box is arranged are determined by the number of times the signal is received at the central office.

It may be noted that all "call" signals end with an even figure to distinguish them from the burglar alarm signals which end with an odd figure. This system of calls being the usual method adopted by all District Telegraph Companies, for signaling from a distant point to a central office. No special claim is made for it excepting as it enters into the arrangement of the following described exhibits:

THE CLOSED CIRCUIT BURGLAR ALARM SYSTEM.

The doors and windows having been connected by closed circuit springs to the burglar alarm box placed in the building, the action may be substantially described as follows:

The box contains the circuit-breaking wheel before described, a pair of magnets to actuate an armature and a pivoted shaft to hold the circuit wheel in check. The main circuit is brought in and connected to each side of the pair of magnets,—after passing through the circuit wheel and connection spring, and, at these points the shunt or wire passing through the building and fastened to the spring, is also connected. When the shunt is closed by the closing of each and every door and window, the clock-work is wound up and the circuit wheel is caught and locked by the pivoted shaft, at the same time a plate drops in front of an opening in the box face and shows the word "set." The main circuit now passes from the point of connection over the shunt, which offering a very much less resistance than the magnets cuts them out so long as the shunt is kept closed. Should any door or window now be opened, and the shunt be broken, the circuit passes through the magnets, attracting the armature which trips or throws off the detaining shaft and releases the clock-work. The magnets having performed their work, are, by a very simple device, cut out of the main circuit, and the circuit wheel and connection spring are alone left in the line circuit.

By the use of a simple device the magnets may be thrown into circuit, the box not being wound up, and should any portion of the shunt be open the armature will be attracted and a clicking sound be heard, which will not be possible if the shunt is closed and intact. The signal of the burglar alarm is transmitted five times. It is claimed that this system is a perfect closed circuit "alarm," by which it is not possible to leave any portion of a building, connected by this method, open or unprotected, as the shunt must be closed in its entirety to wind up and "set" the alarm box.

The protective or cabinet system consists of a wooden case or covering, the inner surfaces of which are lined throughout with wires, which, being securely fastened in both directions upon the surfaces, forms a perfect protection. This case may be used as a cabinet, simply, or as an enclosing case for a safe. It is connected by wire with a central office having special appliances for receiving notice of the closing as well as the opening of the case. It is claimed for this system that it is a perfected method of protecting safes, vaults and rooms by an electric covering which cannot be broken through, cut out of circuit, or in any manner tampered with, after having been closed and placed in connection with a central office, by any one—expert burglar, electrician, or any other person.

THE POLICE SIGNAL SYSTEM OF THE MUNICIPAL SIGNAL COMPANY OF BOSTON.

This system provides means of intercommunication between the policemen on their routes and the commanding officer at the police station, by signaling apparatus designed for the purpose and also by telephone, the latter being used solely as an adjunct to the signaling portion of the system. The exhibit comprises a station house apparatus and a policeman's beat equipped with two signal boxes or stations and a telephone station, the stations being connected with the station house instruments by two metallic circuits, one for signals and the other for telephones. The station house instruments consist of two relays, one on each side of the signal circuit, their armatures controlling two ink recorders after the manner of district or fire alarm telegraphs. One of these recording instruments registers the "on duty," or "patrol" signals of the policemen, while the other only records the "alarm" signals. The signals are regulated by the introduction of a greater or less resistance, the less resistance being used for the patrol and the greater for the alarm signals. The station house is also provided with a transmitter capable of transmitting any one of a hundred numbers, and it is provided with an index dial and pointer for convenience in setting it in position to transmit any desired number. The transmitter itself is of ingenious construction, being a concaved drum, having the circuit controlling contact points for each number grouped thereon longitudinally, the various signals being arranged side by side round the drum. Four revolving arms, moved by a clock-work motor, controlled by detents and having flexible contacts at their extremities, which, when revolved, successively co-operate with the contact points on the concave surface of the drum, close and open a local circuit controlling a pole changer whereby the main battery on the signal circuit is reversed whenever the revolving contact in co-operation with one of the drum contacts, closes the local circuit of the pole changer. The street signal boxes, when their doors are open, expose dials having nine different signals or calls conspicuously displayed thereon, such as "Aid," "Wagon," "Riot," "Ambulance," etc., and should a policeman require "aid," "wagon," or anything inscribed on the dial, he has merely to move an index finger to that desired, and then give the alarm, which causes characters, such as dots and dashes to be transmitted over the circuit and recorded at the police station, indicating to the person in attendance the nature of the aid and the locality where it is wanted. The closing of the door of the signal box restores the indicator to its normal position. Citizens may have keys issued to them, numbered and registered at police headquarters, and they can give a police alarm from any signal station by merely inserting the key in a "citizen's keyhole," underneath the door of the signal box, turning it as far as it will go, and then releasing it, and a policeman can likewise, in an emergency, give a call for assistance in like manner, without being obliged to open a door of any kind.

The telephone stations, as shown in this exhibit, are separate from the signal stations, but they each bear a number to distinguish them from each other, as do also the signal stations. It is claimed that the telephone stations can be combined with the signal stations.

Policemen can send in their "on duty" signal from the signal boxes in rotation, at certain definite times, and these signals are received on the patrol register at the police station, and, at the same time, the transmitter is automatically brought into action and transmits over the circuit whatever number is in position for transmission, ringing it on a bell inside of the street signal box, by means of a polarized magnet and armature, the policeman being informed by the number he hears whether he is wanted at the telephone or at some other signal station.

The chief merits claimed for this system are: complete control of the policemen by their commanding officer; rapid and efficacious communication of policemen and citizens with police stations, and separate and independent recording instruments for alarms and "on duty" signals on a single circuit. It is also claimed that if an "on duty" signal and a "call" signal be given simultaneously that the "call" signal will be registered notwithstanding the "on duty" signal, the interference not affecting the more important, or "call" signal, owing to the higher resistance introduced into the circuit.

The mechanism by means of which the signal boxes are operated was not shown to the committee.

THE PORTER AUTOMATIC ELECTRIC SIGNAL AS A FIRE ALARM SYSTEM.

The principle of the circuit is known as the earth or ground connections; that portion, however, which is outside of the office is metallic, the grounded ends being under control of the operator at the station.

At each end of the circuit there is a system of relays and local signal. On one of the ends there is a rheostat for the purpose of increasing or diminishing the resistance of the circuit. The ordinary method for using this is to "put in" as much resistance on the rheostat end of the circuit as will enable the tension spring of the relay at the outgoing end of the circuit to overcome the magnetic attraction on the armature, thus holding it away from the poles until the resistance in the circuit is reduced when the magnetic attraction will overcome the tension spring and a local alarm is the result. The relay on the rheostat end of the circuit is operated just the reverse of the one at the battery end, the adjustment being made so that the magnetic attraction barely overcomes the tension spring; so that the slightest falling off of magnetic attraction will permit the tension spring to draw the armature back, when the other local alarm system will be operated.

Each signal box has an earth connection, which is brought into use only when the box is operated so that, by giving a signal, a ground is established through the circuit breaking wheel, the circuit being broken by the same operation, as the wheel revolves, the combination giving the number of the box is consecutively made and repeated three times. It is claimed for this system of signaling that on one side the circuit might be entirely destroyed, while the signal would come into the office all right on the other side. It is also claimed that the operator is made aware of the slightest changes in the condition of the circuit and without leaving his station can instantly switch in a reserve battery or even utilize a "ground," "break," or "cross" to do the work of signaling.

EXHIBIT OF PARTICK & CARTER.

The novelty of device, mechanism, etc., which is claimed for the annunciators and alarms in the above exhibit, are:

1. A perforated zinc plate acting as a dial and support for the pointers, and in the smaller size performing the part of tripping or restoring mechanism without any farther mechanism being necessary than a pair of hinges at the top of plate. The plate, or dial on being moved forward, breaks the contact between the pointer and the magnet core; no amount of jar or hard usage will throw this plate out of place or adjustment, a very important point when the rough handling of kitchen and other annunciators is so apt to throw delicately constructed mechanism out of order.

2. The small number and great simplicity of the parts, there being only one magnet and a pivoted needle or pointer necessary for each indicator or number, thus reducing the number of parts to a minimum, the simple pointer doing the work of several parts.

3. In the large or hotel annunciators the same mechanism is employed as in the smaller, with the exception that the dial is stationary,

the tripping mechanism being merely a system or number of brass strips carrying pins projecting through slots in the dial. These pins press the pointer away from the magnet core whenever the trip handle is moved. Only the pointer that is indicating is moved by this arrangement.

4. Owing to the extreme simplicity of this apparatus a very small battery power is required to operate the annunciator.

5. All bells placed in these annunciators are mounted on iron frames, so arranged that it is almost impossible to put them out of adjustment.

6. The needle or pointer can be made of steel or iron, as permanent magnetism is not depended upon to cause it to adhere to the core of the magnet, residual magnetism being sufficient.*

The committee regret that they were not furnished with more lettered diagrams of the exhibits as thereby the explanations could have been more clearly set forth.

In some instances it was found that the persons in charge of the exhibits were not as fully competent to explain the workings thereof as the committee would have desired.

[SIGNED.]

DAVID R. WALKER, *Chairman*.
WM. ATLEE DRYSDALE, HUGO BILGRAM,
DAVID BROOKS, LOUIS H. SPELLIER,
E. ALEX. SCOTT, THEO. D. RAND.

ENDLESS WIRE SAW.—M. Vialatte has invented a new saw for stone-cutting. It consists of an endless metallic cord composed of one or more soft steel wires, twisted together and subjected to a continuous movement in a uniform direction, and fed with siliceous sand or grit. The sand is mixed with water, as in ordinary stone-sawing, in order to facilitate its penetration to the bottom of the crevice and to prevent heating. The apparatus can be easily set up, taken down, or transported from place to place, and one of its great advantages is the readiness with which it can be used in quarries, so as to avoid superfluous transportation. Tissandier speaks of it as "the butter-cutting wire, used for sawing stones."—*La Nature*, May 17, 1884. C.

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* Here follows diagram of connection for the Patrick & Carter alarm, which the committee do not think it necessary to reproduce.

CORRESPONDENCE.

Committee on Publication of the Journal of the Franklin Institute:

GENTLEMEN:—In the February number of the JOURNAL for 1882, I gave to your readers a paper upon a "New Theory of the Suspension System with Stiffening Truss." In that paper I advocated the use of a truss fixed horizontally at the ends and continuous at the centre, and gave the mathematical discussion of such a truss, so far as I know, for the first time. Previous writers have assumed that the curve of the cable for a partial loading remains unchanged, such a partial loading being distributed over the cable by means of the truss, and the cable therefore retaining its parabolic shape. This assumption I repudiated, and introducing instead of it the condition that the *horizontal pull* of the cable remains practically the same as if its form were unchanged, I applied the received theory of flexure to this system, and as I think, completely solved the case. I need hardly say that no such structure as yet exists, to my knowledge, as such a suspended truss, and I put forward the combination as a new one, which would be found stiffer than any of the known forms of suspension, and which could by means of my formulæ be completely calculated.

I have just received a letter from C. B. Bender, C. E., member American Society of Civil Engineers, from England, enclosing a hectograph copy of a paper upon "Suspension Bridges of any Desired Degree of Stiffness," written by him May 28, 1881, upon which he claims priority for the theory. This paper I had never seen, and my solution was independently made; still it is but simple justice to Mr. Bender, and it is the object of this communication to state to all interested, that so far as the *general method* of solution is concerned, by the application of the theory of flexure to the suspension system in such a way as to avoid the incorrect assumption hitherto made, Mr. Bender's claim of priority is fully made out. As the entire originality of the discussion from a mathematical standpoint, lies in this, such credit as there is in it belongs to him.

So far as my treatment of the special case supposed, *i. e.*, ends horizontally fixed and centre continuous, is concerned, it still remains the only solution I know of. This solution is but a special case of Mr. Bender's more general discussion, however, and one which he might easily have made had he chosen so to do. The special case to which he did apply his method, was that of a stiffening truss *hinged at the centre* and *supported at the ends*. Our actual solutions, therefore, are widely different. This much is due to myself, as, owing to the fact that Mr. Bender is about to bring out a work which will contain his theory, and his undoubted claims to priority in the general method, as well as the similarity of much of the notation employed, I might otherwise be placed in an unenviable position.

Yours very truly,

A. J. DU BOIS.

NEW HAVEN, CONN., November, 1884.

Book Notices.

TESTING MACHINES; THEIR HISTORY, CONSTRUCTION AND USE. By Arthur V. Abbott. New York: D. Van Nostrand, 1884.

But few engineers have opportunities equal to those of the author, for acquiring practical experience in the modes of testing the strength of the various materials used in architectural structures and works of engineering, and a compilation of such experience cannot fail to be of considerable value to all engineers. The author has, indeed, in the above-cited concise treatise, done full justice to the task he has undertaken.

After giving a brief sketch of the history of testing machines, he describes a number of such machines, as produced by various makers, giving his views of the merits and demerits of the same, without fear or favor. He then describes and analyzes the phenomena attending the tests of various materials, giving to others the benefit of his labor and experience.

H. B.

THE PHILADELPHIA INSURANCE CHART FOR 1884–1885. By J. H. C. Whiting. Philadelphia: Review Publishing and Printing Co.

This annual insurance chart, which this year appears in convenient pocket-book form, is a model of condensed information in regard to the specialty insurance. It contains a complete directory of all insurance companies, and insurance agencies and brokers doing business in Philadelphia. Part of the value of this work is a compendious table of Philadelphia fires for the decade 1874–1883, thoroughly classified, and giving the number, amount of losses and insurance, with the percentages of losses. This chart also contains much valuable local information of a miscellaneous character.

N.

ELEMENTARY TEXT-BOOK ON PHYSICS. By Prof. Wm. A. Anthony and Prof. Cyrus F. Brackett. New York: John Wiley & Sons, 1884.

A text-book that gives in concise language and logical sequence the modern ideas of physics, unencumbered with obscure mathematical expressions that place it beyond all but a limited class, has long been needed. It is fortunate for the student of physics that gentlemen so capable as the authors have been willing to undertake the work, and we heartily congratulate them on the result. They have placed before the general public, as well as the average college student, a clear, fresh, and accurate work on physics, that will acquaint its readers with the latest developments of the science. The book is the work of scholarly minds, trained in the art of teaching. Throughout its pages expressions and methods of presentation of ideas abound, that bear the impress of the practical teacher.

The book is not wanting in the necessary application of mathematics to the solution of physical principles. It will, indeed, necessitate on the part of the student a thorough mathematical training in algebra, geometry and plane trigonometry, and, indeed, in some few cases, in analytical geometry, though these last may be omitted without serious lack of continuity.

Part I of the work, which is before us, contains 246 pages. It gives in its introductory matter, concise, illustrated descriptions of apparatus used in the measurements of space and time. Chapter I, treats of the Mechanics of Masses. Chapter II, of Universal Attraction. Chapter III, of Molecular Mechanics, and Chapter IV, of the Mechanics of Fluids. This chapter completes Book I.

Book II which completes this part of the work, is devoted to the consideration of the production and nature of Heat. In it will be found full explanations of the modern ideas of heat. The closing chapter on Thermo-Dynamics is especially to be commended.

Part II will include the subjects, Electricity and Magnetism, Acoustics and Optics.

We regret that the value of this book should have been impaired by the absence of an index. We believe, however, that the authors intend placing an index at the end of the completed work. E. J. H.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December* 17, 1884.]

HALL OF THE INSTITUTE, December 17, 1884.

MR. WILLIAM P. TATHAM, President, in the Chair.

Present, 138 members, and 11 visitors.

Twenty-one (21) persons were elected members of the Institute since the November meeting.

The following nominations for officers, to be chosen at the annual meeting in January, were made:

For President (to serve one year), William P. Tatham.

For Vice-President (to serve three years), Joseph E. Mitchell.

For Secretary (to serve one year), William H. Wahl.

For Treasurer (to serve one year), Samuel Sartain.

For Managers (to serve three years; eight to be chosen), William Sellers, J. Vaughan Merrick, Hector Orr, William D. Marks, Cyrus Chambers, Jr., Charles J. Shain, Henry R. Heyl, Hugo Bilgram, G. Morgan Eldridge, Charles E. Ronaldson, M. B. Snyder.

For Auditor (to serve three years), William B. Cooper.

For Representative in the Pennsylvania Museum and School of Industrial Art, William H. Wahl.

Mr. W. Barnet LeVan presented a series of views, exhibiting the time tables of the fastest trains on the principal European and American railways, and commented upon the same. An abstract of Mr. LeVan's remarks has been referred to the Committee on Publication.

The Secretary, in his report, made some further references to the experiment of purifying the Schuylkill water by aëration, in connection with which, he presented a communication from Col. William Ludlow, Chief of the Water Department of Philadelphia. The subject was discussed by Messrs. W. B. LeVan, William B. Cooper, Dr. Mintzer, Hector Orr and others.

The Secretary presented a view of the American Isthmus, exhibiting the location of the principal projected canal and railway routes, with remarks upon the salient features of each.

The Secretary also called attention to the alleged inadequacy of the facilities and equipment of the United States Patent Office, by reason of which the inventors of the country and the great business interests represented in patent property were subjected to unjust, unnecessary and expensive delays in the transaction of business with the office. He quoted from the last published annual report of the Commissioner to show that there were, on June 30, 1884, awaiting action in the office 9,186 applications, or 5,087 more than were awaiting action at the corresponding period of the year 1883; and that the decision in the telephone interference cases, arguments in which closed in November, 1881, was not reached until July, 1883, and was not confirmed on appeal until two or three months ago; and that, in some of the classes, the number of pending cases was so great that there was no probability of a new case receiving attention for six months or even longer. This was especially the case in the class of electrical inventions, in which, in August last, over 600 applications were awaiting their turn.

The Secretary's report embraced, also, remarks upon the new local anæsthetic (the hydrochlorate of cocoaine); and the description of the following new inventions: Dr. Cook's improvement in Apparatus for Administering Anæsthetics; Joseph H. Black's improvement in Car Wheels; R. Baumgardner's Metallic Cross-tie for Railways; Edward B. Meatyard's Acme Railway Car; and the so-called Willesden Fabrics. These last consist of paper, canvas, cordage, etc., which have been treated with cupro-ammonium solution, by which they have been rendered water-, rot-, mildew- and insect-proof. The fabrics are adapted for a great variety of uses. [For a full description of these, the reader is referred to the *Journal of the Society of Arts* (London), May 7, 1884; Art. Cupro-Ammonium Products, by Dr. Alden-Wright.]

On Prof. E. J. Houston's motion, seconded by Prof. M. B. Snyder, the following preamble and resolutions were adopted, after prolonged discussion:

WHEREAS, Scientific books published abroad are absolutely essential to students and investigators, and are but rarely duplicated in this country, therefore, be it

Resolved, That the Franklin Institute of the State of Pennsylvania hereby requests the Representatives of Pennsylvania in the Congress of the United States to use all possible exertions to have private parties importing such books for their own use and not for sale, placed upon the same footing as colleges and other incorporated institutions.

Resolved, That a copy of this preamble and resolutions be forwarded to each Member of Congress from Pennsylvania.

The subject of holding a special Exhibition in the autumn of 1885, was again referred to the Board of Managers as urgent.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

The Franklin Institute.

[Abstract of the Proceedings of the Stated Meeting held Wednesday December 17th, 1884.]

Mr. W. Barnet Le Van presented a series of diagrams exhibiting the time tables of the fastest railway trains of Europe and America, and made the same the subject of some interesting comments on "Modern Railway Facilities." "Eighty years ago," said Mr. Le Van, "Oliver Evans, in the streets of this city, made the first application of steam to a carriage in America. He prophesied that the time would come when a passenger 'will set out from Washington in the morning, breakfast in Baltimore, dine in Philadelphia and sup in New York the same day.' Mr. Evans gave a description of what he supposed would be the future railroad, but the event has surpassed his greatest expectations." Answering the question, often discussed, as to which railroads run the fastest trains, the speaker, referring to his diagrams, made substantially, the following statements: "On the Manchester, Sheffield and Lincoln railway, there are 16 trains daily between Manchester and Warrington, which go over the 16 miles intervening in 18 minutes, or at the rate of 53 3-10 miles per hour. On the Great Western, the celebrated "Flying Dutchman" is run, which train makes the 77 miles between Paddington and Swindon in 1 hour and 27 minutes, or at the rate of 53 2-10 miles per hour. This train has been running on the same time schedule as at present for the past 20 years. The express between Grantham and Wakefield on the Great Northern Road travels the 70 miles in 78 minutes, an average of 53 8-10 miles an hour. The Scotch roads do not make such fast time as the English, the grades being much heavier. The speed of German roads is also not up to that of the English."

In this country the fastest short distance run is made on the Baltimore and Ohio, between Baltimore and Washington. The distance is 40 miles, and is made in 45 minutes, the speed averaging 53 3·10 miles per hour. This is equal to the best short run abroad. On the Bound Brook route the 27 miles between Trenton Junction and Bound Brook is made in 31 minutes, or at the rate of 50 miles per hour. The Pennsylvania Railroad runs a train between Germantown Junction and Jersey City at the rate of 49 4·10 miles per hour, though having no less than 90 curves in that distance.

But in long distance runs the Pennsylvania stands first in the world. The Chicago limited travels 912 miles in 26½ hours, including 66 minutes in stops, an average of 36 2·10 miles per hour. Mr. Le Van gave a description, in detail, of this train, and of the luxurious accommodations it affords.

The Secretary, Dr. Wahl, in his monthly report, referred to the lamentable inadequacy of the facilities and equipment of the United States Patent Office, and suggested that some action be taken by the Institute in bringing the needs of the office to the attention of the National Congress, which had hitherto neglected to act upon the requests and recommendations of successive Commissioners. It was shown that the average annual surplus of the Patent Office for the five years ended December 31, 1883, had been $285,992, all of which is contributed by the inventors in the form of fees. Under these circumstances. they have surely the right to ask that their business shall be dispatched, efficiently and promptly.

The facts are, however, that in respect to the number of examiners, assistants and other employés, and the accommodations and facilities afforded them, the forces and equipment of the office are quite insufficient to dispose of the business as rapidly as it accumulates. The report of the Commissioner for the year ended June 30, 1884, exhibits the fact that on that day there were no less than 9,186 applications for patents awaiting action, or, 5,087 more than at the corresponding period of 1883. In the class of electricity alone the number of pending applications in the month of July last, exceeded 600. The legal business of the office is equally backward ; important cases involving priority of invention, requiring several years for their decision. These harrassing delays impose needless hardships upon the inventors and frequently very seriously impair the value of their inventions.

The Secretary alluded to the experiments that were being conducted under the direction of Chief Engineer Ludlow, of the Water Department of Philadelphia, with the object of purifying the water supply by a system of artificial aëration. These experiments had proved very encouraging, and promised to yield important practical results. The plan employed, which is that suggested by Dr. Albert R. Leeds, differs from others that have been employed for a similar purpose. Laboratory experiments made by Dr. Leeds indicated that the advantageous action of atmospheric air in modifying and, in part, removing the impurities of water in contact with it, was greatly increased by producing the intermingling of the two fluids under pressure. The greater the pressure, the greater is the absorption of oxygen, and consequently the greater the reduction of the impurities. The precise measure of this increase has not yet been ascertained. In order to try the experiment on a larger scale, and in such a manner as to afford some evidence of its value in practical operation, one of the Fairmount turbine engines (No. 8) was altered so as to convert it, in part, into an air-pump, by simple mechanical artifices unnecessary to describe. The result reached by the action of the pumps thus modified, was the delivery of about 20 per cent. by volume of free air into the water discharged into the main, this proportion being that which had been shown by experiments of Professor Leeds to be sufficient to surcharge the water.

By subsequent comparison of samples of water from the Fairmount pool taken into the pump, and of the water discharged into the Corinthian basin after passing through 3600 feet of main, the results of the experiment were made apparent. The percentage of oxygen in the aërated water was 17 per cent. greater than before; that of carbonic acid was 53 per cent. greater; and that of the total dissolved gases 16 per cent. greater. The percentage of free ammonia was diminished to 1-5 of its former amount. The percentage of free oxygen represents the excess over and above what was required to effect the oxidization of the organic impurities. These results are most favorable, and point clearly to the entire feasibility of reducing the percentage of organic matters contained in water unduly contaminated with sewage, within the limits of safety.

The Secretary spoke of the several projects for canals and railways across the American Isthmus, and illustrated his remarks with the aid of a photographic map of the Isthmus, of which an image was projected on a screen with the lantern. He exhibited an Edison glow lamp, in which the copper, with which the juncture of the wires with the carbon filament is electroplated, had been volatilized by the heat of the lamp. The metal had been deposited very uniformly on the interior surface of the globe, forming a continuous copper coating of superb metallic lustre when viewed by reflected light, but so excessively thin as to be quite transparent by transmitted light, the transmitted color being green, or the complementary color to the first named. Similar effects have often been observed with the Edison glow lamp, but the specimen shown was remarkable for its extreme beauty.

Professor Houston offered a preamble, setting forth that scientific books published abroad, are absolutely essential to students and investigators, and are but rarely duplicated in this country, and a resolution that the Franklin Institute send a request to the representatives of Pennsylvania in Congress to use their utmost endeavors to place private parties, who may import such books for their own use and not for sale, upon the same footing as colleges and other incorporated institutions. The resolution was adopted.

The project of holding an exhibition on some special subject evoked considerable discussion. WILLIAM H. WAHL, *Secretary.*

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ELECTRO-METALLURGY.*

By Nathaniel S. Keith.
Secretary of the American Institute of Electrical Engineers, editor of the "Electrical World," etc.

Mr. Keith, who was introduced by Dr. William H. Wahl, Chairman of the Lecture Committee, spoke as follows:

Ladies and Gentlemen:—I have this evening that which may be called a dry subject upon which to speak. I shall do my best to make it interesting to you, but cannot hope to succeed in imparting a full knowledge of the subject in one short lecture. It is a subject of intense interest to the chemist and to the electrician, for it combines principles underlying its practice which belong to both professions. In fact, the man skilled in its science and art may appropriately be styled an electro-chemist.

The art is only of comparatively recent growth. Its fundamental features have come to light, from time to time, only during the past century of years, and its principles have only been outlined, investigated and understood during the last thirty or forty years. Its broad, extensive and economical practice has only come to be possible within the last decade—since the practical development of dynamo-electric machines, such as we see in this Exhibition in such great variety of forms and capacity, at work producing electricity for lighting and other purposes.

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*A lecture delivered at the International Electrical Exhibition of the Franklin Institute, Tuesday, September 23, 1884.

Unfortunately there is but a poor exhibit in numbers of dynamo-electric machines specially constructed for electro-metallurgical work. We will presently consider what this special construction should be.

We might devote considerable time to an account of the history of the art; but there is so much more of practical interest to be considered in the way of experiments and descriptions during the time allotted to me, that I will only glance at the course of its rise.

The art may be said to have originated with Volta, who made the first chemical electric battery, and demonstrated that metallic salts could be decomposed into their constituent parts, and that water could be resolved into gases—oxygen and hydrogen. This was in the year 1799. After this time there were many experimenters with the voltaic pile and with various voltaic batteries in producing the electro-chemical decomposition of various metallic salts in solutions; but it was not until after 1830, fifty years ago, that the facts known came to be applied to any practical purpose. About this time the form of voltaic battery called the Daniell cell was invented by Daniell.

During the few years immediately succeeding the year 1830, Jacobi, Spencer, De la Rue, Daniell himself, and others were experimenting with this battery for various purposes, but mainly in the way of discovery. Some, if not all of the experiments which I am about to show you were performed by these distinguished men. Many of these things, which now seem to us so common and obvious, were then the subjects of great wonderment and of scientific discussion.

So, then, when either Spencer or Jacobi first announced that the deposit of copper, which takes place in a Daniell cell, could be removed from the metal upon which it had been deposited and that the face of the removed deposit had in reverse all of the marks, whether depressions or protuberances of the face of the metal which had received the deposit, it excited much notice and comment, in fact a scientific *furore*. The Daniell cell, by the way, is a good illustration for us to consider in relation to the principles of electro-metallurgy; therefore we will take it up later on.

Experimenters and inventors took the facts that had accumulated at that time, and from them and others evolved the art of electro-metallurgy, which has scarcely been improved in conception and execution during the past twenty years. The improvements, or such new things as I may so designate, are in the manner and means of producing electricity and in special applications of electricity so produced. The modern practical electro-metallurgy rests upon the principles and speculative ideas of men of 30 or 40 years ago, and on the more modern dynamo-electric machine, by the aid of which we are able to produce electricity in any quantity, any quality, more reliably, with far less trouble and for less than one-twentieth of the expense incurred with galvanic batteries.

The principles and laws governing the art of electro-metallurgy were well laid down by Smee, who wrote a book on the subject in 1840. The book made Smee famous, and his name will always be coupled with the art on which he conferred the name, "Electro-Metallurgy." We are now able, with the latest modern appliances for the production of electricity, to apply the principles laid down by Smee to the renewed art, made so much broader in its scope, because so much more economically and reliably to be pursued. I refer more especially to production and purification of metals, and the separation of them from one another, and the production and reproduction of works of art and to similar purposes.

Enough has been said about the history of the art; we will, therefore, proceed to consider its principles, and we can best do so by showing a few experiments and making remarks upon the phenomena which you will observe. We have here a lantern which will produce upon the screen a picture of those things which my assistant may put before it.

I have had prepared several glass cells, containing different liquids, and we will place them in succession before the lantern, and their contents will be shown on the screen, and we will also be able to see the actions which go on in the cells. By considering these things I hope to be able to give you a pretty fair idea of the principles involved in this beautiful art.

We have in this first cell dilute sulphuric acid. We immerse in it a rod of the metal zinc. Observe the action. Bubbles of gas form on the zinc, rise rapidly to the surface of the liquid and escape in the air. Now, whoever first noticed this phenomenon did not know what this gas was, nor the reasons for the appearances. Many years of experimental research and indulgence in hypothesis, theory and controversy were spent before the conclusions we now state as facts were adopted in relation to this and the other points which we will consider to-night. But our time is too short to allow us to indulge in anything but a statement of facts, and accepted theories for the facts, we may observe. The gas is hydrogen; it comes from the water of the diluted sulphuric acid; water is composed of oxygen and hydrogen; the oxygen has combined with the zinc to form oxide of zinc; the oxide of zinc is dissolved by the liquid because some of the sulphuric acid radical (SO_3) combines with the oxide of zinc to form sulphate of zinc ($ZnSO_4$), which is soluble in water. This action will continue until all of the zinc is dissolved, or until all of the acid constituent of the liquid is exhausted. Then, in the latter case, oxide of zinc will be formed as a sort of coating over the metallic zinc. This coating, being insoluble in the water remaining, will act to protect the zinc from further chemical action.

We observe that the liquid rises in temperature as this action proceeds. What do we deduce from that? Heat is a manifestation of active energy, that is, energy which is being freed from one material and being absorbed by another or others. But where does this energy come from? When the zinc was separated from the mineralizing constituent, oxygen, (which compound constituted its ore) heat was used to effect the decomposition, and a portion of the energy which the heat represented was absorbed by the zinc, and became *latent* as it is sometimes expressed.

Now, metallic zinc has a continual tendency for union with oxygen, and such union takes place whenever the conditions are favorable. In uniting again with oxygen, just as much heat is given out as was absorbed during the process of freeing it from the oxygen originally combined with it in the ore. Immersion of zinc in dilute sulphuric acid is a condition extremely favorable to its oxidation. As zinc under these conditions has a greater affinity for oxygen than hydrogen has, it displaces the equivalent of hydrogen and combines with the oxygen, with production of heat, which shows itself in the elevation of the temperature of the dilute acid. Conversely: if we separate the zinc from the oxygen and the acid, we must, to so do, apply energy in some of its modes, such as heat or electricity.

Now, in the second cell which I will bring to your notice, I have some of the same dilute sulphuric acid, and immersed in it are two rods of metal. One of these is of copper and the other of zinc. But the surface of the zinc is covered with mercury, for the purpose of protecting the zinc from direct action of the acid on it. Mercury has been found to perform this office, and without impairing the qualities of zinc for the purposes of the galvanic battery.

You will observe that as long as the two rods are separated the liquid remains quiet, there is no boiling—escape of gas—as in the former experiment. We learn, by the fact of the copper rod being unaffected, that copper has less affinity for oxygen than hydrogen has; and that, although zinc has a greater affinity, it is prevented from exercising it by the protective coating of mercury which has even a less affinity for oxygen than has copper.

By carrying on a similar line of experiments with other metals and other liquids we would learn that the various metals have differently valued affinities for oxygen, some more than others, so that a scale-list may be made out in which the metals will be arranged in the order of their several affinities for oxygen, or for chlorine. Those which have the strongest affinities are called electro-positive, while those with less strong affinities are called electro-negative in relation to the others. Thus every metal, except the extremes of the list, is electro-positive to some of the list and electro-negative to the others.

Now, if we touch these two metal rods together, immediately torrents of gas bubbles are seen to proceed from the surface of the copper rod, rise to the surface of the liquid and escape into the air. It will also be noticed that the action is even more violent than in the first instance. If we separate the rods the action ceases at once, and is immediately resumed on retouching.

The gas escaping is hydrogen, as in the first experiment. But it rises from the copper instead of the zinc. The copper, however, is not dissolved, but the zinc is, as before; and the action will continue as in that case. So far we have not seen any evidences of electricity. But if we connect the zinc and the copper rods by means of a wire running through some electrical instrument, say a galvanometer, that magnetic action takes place in the instrument, which, we know, shows the existence of a current of electricity.

This experiment is often shown in illustrating the genesis of the galvanic battery. A galvanic battery is but an electro-metallurgical apparatus. The principles which govern batteries are electro-metallurgical, because they are those which govern the affinities of metals both in the production and utilization of electricity.

It has been found that the setting free of gaseous hydrogen absorbs some of the energy of the union of zinc with oxygen and acid. This is the case whether in a galvanic battery, or in an electrolytic bath wherein electricity is effecting chemical changes. Therefore it is desirable to avoid this formation of free hydrogen. In some galvanic batteries this is done by providing at the copper rod, or plate, (or at the negative material) some material which will absorb the hydrogen as fast set free. In electro-metallurgy, strictly speaking, this is also desirable, in order to avoid waste of energy which necessitates the use of more materials in the shape of coal or chemicals to produce the electricity needed to supply the waste of energy in the electrolytic bath.

I am showing and explaining these elementary experiments to illustrate, step by step, some of the principles which govern electro-metallurgical problems, and for use subsequently when I come to the applications of the principles involved.

In the two experiments just shown, hydrogen gas has been shown in both. I have arranged an experiment in which oxygen is set free. But previously to showing it, I will give another in which a metal is set free. The liquid in this vessel is an aqueous solution of acetate of lead, commonly called sugar of lead. After we immerse this rod of zinc in it, as we did in the case with the dilute acid, instead of bubbles of gas escaping, the rod appears to increase in diameter with a gradual growth. We learn from this experiment that zinc reduces lead from its solution, enters into solution in place of the lead, in a manner analogous to the substitution to produce hydrogen. But as lead is not gaseous, it remains in the liquid clinging to the remaining zinc. This action will continue until the zinc has completely been dissolved, or until all the lead in the solution has been reduced from it to a metallic state. The liquid also rises in temperature, but not so much as in the first or second experiments. This is because the production of metallic lead absorbs some of the energy set free by the zinc, and that energy is not used to heat the liquid.

It will be noticed that the reduced lead is in a very finely divided state, an aggregation of minute crystals appearing to the eye like a flocculent mass. This is generally the case under like circumstances with all metals reduced from their solutions by other metals.

In the experiments thus far shown we have seen the substitution, merely of an electro-positive metal for some electro-negative constituent of a solution. We have learned that this action sets free the amount of energy which belongs to the union of the electro-positive metal with oxygen and acid, over and above that energy which belongs to the like union of the electro-negative material with the same constituents; and that this extra energy is manifested as heat in the increase of temperature of the liquid.

Now, from our other observations, it is plain, that if we desire to substitute electro-negative materials for electro-positive ones in liquids we must apply energy in some form to the liquids containing such constituents. Heat alone does not suffice; but electricity does, so that we are enabled to make many of these substitutions which can only be made, if at all otherwise, by long, tedious, and expensive chemical and metallurgical processes. Chemical and metallurgical processes are merely those of substitution of one material for another, during which energy in some of its modes takes active part, either to be set free or absorbed. Electricity is the most manageable mode of energy, and it seems that by its aid, being so easily controlled, a much wider use of it in chemistry and metallurgy is to be made than now. Especially is this the case since its production in any quantity and quality is so cheap and easy by means of dynamo-electric machines.

I have prepared an experiment *apropos* to this stage of my lecture, which, though it is an old one, familiar to many of you from your school days, I shall venture to repeat it here.

In this vessel is dilute sulphuric acid, and two platinum strips separated from each other. One of these platinum strips is connected by a wire with one of the poles of a galvanic battery, and the other strip with the other pole of the battery. Platinum is used because its affinity for oxygen and acid is so slight that even an electric current will not cause them to unite. You will observe that, now the battery circuit has been completed, torrents of gases escape from both the platinum strips, and that from one of them twice as much in volume is produced. The lesser volume is oxygen and the other hydrogen. The galvanic battery supplies the energy needed to effect the decomposition of the water; and more energy, this is more battery power, is required than would be the case if the strip from which the oxygen is escaping was of a metal which would absorb oxygen and be dissolved by the acid liquid. Because this latter action would contribute some energy (that due to the union of the metal with oxygen and acid) to the circuit of the operation.

I have three cells of Daniell battery connected in the order called "series," so as to have sufficient electro-motive force, (or pressure) of electricity to effect the decomposition. Neither one nor two cells will furnish pressure enough. From this and other experiments of analogous character with other liquids we learn that various electro-motive forces are requisite to effect decompositions of various liquids. We also learn that the needed electro-motive forces are also varied by the kinds of metals which are in the liquids and connected with the poles of the battery.

The vessel and contents are called the "bath." The liquid is called the "electrolyte." The metals, collectively, are called "electrodes." That metal which is connected by the wire to the positive, or copper plate of the battery is called the "anode;" and the other metal which is connected by its wire to the negative, or zinc plate of the battery is called the "cathode." And the wires are called the "positive" and "negative conductors," respectively. These names are applied, no matter what may be the kind or shape of the metals, bath, vessel, electrolyte or other parts.

This is the simplest form of electrolytic arrangement, but of little present utility; though it has possible applications in the arts, such as in the production of oxygen and hydrogen gases.

This kind of a bath, modified so as to collect and retain the gases for measurement, is used by the electrician for measuring electricity quantitatively. Such an arrangement is called a "voltameter." Its value as a measure is based upon the fact that a given quantity of electricity effects a given quantity of chemical decomposition, or of chemical composition, as the case may be. This is the case, no matter what may be the composition of the liquid or its contents. A definite current effects a definite chemical action, and one is the exact measure of the other. The only difference physically is in the weight and volume of the respective materials produced by composition and decomposition. Thus a given current will set free 1 grain of hydrogen, 8 grains of oxygen, 31·75 grains of copper, 103·7 grains of lead, 108 grains of silver, and so on with all substances in the ratio of their several electro-chemical equivalents. These electro-chemical equivalents are not always the more modernly recognized chemical equivalents, but are those which represent the chemical equivalent of 1 grain of hydrogen; say, like the older equivalent numbers.

Following these facts we may construct and use copper, lead, zinc and other voltameters for use in measuring electricity. In fact such are used, and with greater advantages in some cases. For instance, the gas voltameter requires a battery as we have seen, of considerable electro-motive force, because the voltameter exerts a counter-electro-motive force, by reason of the fact that no composition takes place in the apparatus. (Remember that decomposition requires energy to effect it, while composition does not.) But we may construct a voltameter which requires no energy, except to overcome the electrical resistance of its parts. For instance two copper electrodes in an electrolyte of a solution of sulphate of copper. In this the composition and decomposition are exactly alike:—as much energy is contributed to the circuit by the dissolving of the copper anode as is absorbed from the circuit by the depositing of copper on the cathode. It is well to remember this for another reason: It is a form of electrolytic bath in most extensive use, and is a type of many others constituted for and of other metals.

We may construct a voltameter which will contribute energy to the circuit. Use an anode of pure amalgamated zinc; a cathode of platinized platinum, and an electrolyte of dilute sulphuric acid. As zinc in dissolving contributes more energy to the circuit than is used in setting free hydrogen, such an apparatus, arranged to retain the hydrogen in a graduated receptacle, may be used in a voltameter, with the understanding that only hydrogen, not the two gases, as in the first case, is to be considered.

The principles illustrated by this experiment and the several analagous ones spoken of, are those which must be closely considered in all electrolytic work; therefore it is well to bear them well in mind.

The next experiment is designed to illustrate the production of a metal from a solution of one of its salts by means of electricity. We have a cell as in the last experiment, and with like electrodes of platinum. But in place of an electrolyte of dilute sulphuric acid, we have an aqueous solution of acetate of lead, the same as in the third experiment. We now connect the battery and we immediately observe gas rising from the anode, and shortly a beautiful arborescent, crystalline, growth taking place on the cathode. We have learned that oxygen under electrolytic action goes to the anode, and when the material of the anode cannot combine with or absorb it, it escapes to the atmosphere. Therefore this gas is oxygen. We have also learned that the metal constituent of an electrolyte goes to the cathode. As the metal constituent of acetate of lead is lead, these beautiful crystals of leaf-like form are of that metal.

Observe how they increase in size. In a short time they will grow until they will touch the anode, and then they will cease to grow because the electrolytic action will cease by reason of the electricity passing from anode to cathode by way of the lead crystals instead of by the electrolyte.

We learn from this experiment that by the aid of electricity metals may be recovered from their solutions; that such is the case only when the metal is more electro-negative than the other constituents; that less battery power is required in this case, at least, than in separating hydrogen from an electrolyte; that the evolution of oxygen requires more battery power than is the case when the oxygen is either absorbed by, or combined with, the material of the anode; and that some at least of the metals are electrically deposited in a separated crystalline state. This is the fact with tin and some other metals. It has hitherto been found impracticable to produce a "reguline," deposit of these two metals. We mean by "reguline," adhesive and cohesive, so that the metal has the characteristics ordinarily belonging to sheets and masses. The reguline condition is that of the greater number of deposits made in electro-metallurgy.

The next experiment which I have arranged is for the purpose of illustrating that which is called "true electrolysis." That is to say, wherein the action and reaction, the dissolving and depositing of metal are in equal quantities. From the anode exactly as much metal will be dissolved as is deposited on the cathode. In this cell both electrodes are of lead, and the electrolyte is a solution of acetate of lead. I use a lead solution because the action can be seen so much easier on account of the character of the deposit pointed out in the last experiment.

Now, when I connect the battery wires with the electrodes there is no commotion in the electrolyte as in the last experiment. The oxygen combines with the lead and the oxide of lead is dissolved by the liquid, while the deposition of lead goes on quietly, and the crystals grow as in the last experiment. We learn by studying the phenomena of this experiment that exactly the same weights of lead are dissolved and deposited; that the electrolysis may go on until the anode be completely dissolved; and that at the end the electrolyte will have as much lead in it as at the start. We furthermore learn that no electric energy is absorbed in this action proper. The only electric energy which is required is that to carry the electricity through the liquid—to overcome the electric resistance of the electrolyte. The energy required to effect the deposition of the metal on the cathode is contributed by the dissolution of the metal of the anode.

The principles of the third experiment—the one in which zinc was immersed in a solution of lead to show the substitution of lead for zinc—are carried into practice extensively, but with another metallic solution, namely, that of sulphate of copper.

In many copper mines, decomposition of the copper ore is continually going on, and copper salts are produced which are dissolved by the waters of the mines. These solutions are called " mine waters." They consist mainly of sulphates of copper and iron. Copper is obtained from this sulphate by a process analagous to the production of lead from solutions by means of zinc; only in place of using zinc, a comparatively inexpensive metal, iron, in the form of scrap-iron, is used.

As the mine waters come from the mine they are caused to flow through long troughs in which are placed large quantities of scrap-iron. As the water passes over this iron the sulphuric acid constituent leaves the copper and combines with the iron, because it has a greater affinity for iron than it has for copper. The copper is left as a dark reddish-brown powder, and is removed from the troughs, from time to time, and smelted to bring it into marketable shape. In place of running to waste as sulphate of copper, iron is substituted for the copper, and it runs away in the shape of sulphate of iron.

If it were possible to prevent oxydation of the iron each 28 pounds of iron would gain 31·75 pounds of copper. But as the iron is generally rusty at the start, and rusts more during the process, the fine powder of copper comes from the troughs much mixed with iron rust, or oxide, and considerable less than the equivalent of copper for the iron expended is obtained. But the expensive copper is gained for the much less expensive waste-iron.

Some years ago I devised a process and apparatus calculated to avoid this admixture. Large vessels contain large porous jars, after the plan of various galvanic batteries, only immensely larger. Iron and slightly acidulated water are placed in the porous cells, and the mine-waters are allowed to slowly flow into and out of the outer vessels, in which thin sheets of copper are placed. The iron in the porous cells is electrically connected by wires with the copper plates. The iron is dissolved and copper is deposited on the copper plates. Electricity is generated by this action, as it is in the cases of all substitutions, and it flows through the wires from copper to iron. This electricity may be utilized for many purposes.

The finely divided copper from mine-waters is called "cement-copper," and is produced in large quantities in South America and other sections. Most of it is taken to Swansea, in Wales, to be smelted and refined.

Some of the mine waters carry silver in solution as well as copper. As iron reduces silver, as well as copper, from its solutions, much cement-copper is produced which contains silver enough to be profitably separated. This separation has been largely done by electrolysis; which operation also, at the same time, refines the copper by separating its other impurities. The cement-copper is laid on an insoluble anode-plate, carbon, for instance, in a solution of copper sulphate. A cathode of copper sheet is suspended horizontally in this electrolyte above the anode. A current of electricity causes the dissolving of the copper while the silver contents, and the gold and other metals electro-negative to copper remain undissolved. When the copper has thus been removed the residues are gathered and smelted for their contents of silver and gold. Iron enters into the solution provided any be present in metallic state or as protoxide. But no iron is deposited on the cathode as long as copper sulphate be present in the electrolyte and in contact with the cathode; and even if no copper be present iron will not be deposited if the electrolyte be acid. If the electrolyte be neutral then iron may only be deposited on the cathode by having the difference of potential (the pressure of the current) between the electrodes greater than that which is due to the difference of electro-motive forces of copper and iron.

The separation of copper from its solutions by means of iron substitution has other applications than that to mine-waters. Solutions of copper are produced in various wet processes for treatment of copper ores. The mother-liquors of the process of making crystals of sulphate of copper must be treated from time to time, when they become impure, for the separation of their copper contents.

It is proposed to use dynamo-electric machines to effect the deposition of this copper. It is claimed that the cost of deposition will be less and a purer product be gained, and this in spite of the fact that more electric energy must be applied to effect the separation than is the case where a soluble anode is used, as in true electrolysis. In this case oxygen must be set free and escape as gas. This requires the expenditure of energy to overcome, not only the electrical resistance of the apparatus and electrolyte, but the difference of the electro-motive forces of oxygen and copper.

The substitution in solutions of one metal for another such as we we have spoken of was known to the ancient alchemists. A base metal could be by simple immersion apparently converted to another, so the charlatans of those days deceived the potentates and rich men of their time into the belief in the transmutation of metals.

By the next experiment I will illustrate to you the electro-plater's art. In this glass vessel I have a solution of silver. It is silver cyanide dissolved in a solution of potassium cyanide. This electrolyte is so constituted for reasons too numerous and complicated to consider at this time. Silver cyanide is insoluble in water, but it is readily soluble in an aqueous solution of potassium cyanide. In this vessel is a plate of silver connected by this wire with the positive pole of a source of electricity; in this case an Edison electric-light machine; the one which furnishes the current for the lights in this hall. The plate of silver is, therefore, an anode; and this plate of copper is to be the cathode of this plating bath.

You will notice that in a short time after I dip this copper plate into the silver electrolyte in the vessel, the copper plate will have received a beautiful dead-white coating of silver. The operation is as follows: The silver cyanide splits into silver and cyanogen. Silver being electropositive in its relation to cyanogen goes to the cathode. Cyanogen being electro-negative in its relation to silver goes to the anode, where it combines with more silver from the anode to form silver cyanide which is dissolved by the potassium cyanide solution. This splitting up and combination goes on continually during the passage of electricity; and the deposit of silver continues as long. Just as much silver enters solution as is deposited, so that the electrolyte may be considered a vehicle for carrying silver across from anode to cathode. When the deposit becomes thick enough, supposing this plate to be an urn, pitcher, knife, spoon or other article, the article is removed, the adhering solution washed off, dried, and then rubbed with a hard, smooth instrument called a burnisher to give it the brilliantly polished appearance so familiar to all of us in silver-plated articles.

This operation serves to illustrate the plater's art. The principles are substantially the same whether the electrolyte be one of silver solution or of a solution of gold, copper, nickel, brass, iron, lead, or zinc. The anode must be soluble in the electrolyte only when energized by electricity. The cathode must be insoluble in the same electrolyte, or otherwise it would be dissolved in the process of substituting its metal for the proper metal of the electrolyte.

Some so-called electro-plating solutions are sold by peddlers and others to the unsuspecting housewives. Many of these plating solutions are such that the articles to receive the coating are electro-positive to silver, and therefore displace silver by substitution. Such coatings are always the merest films, and not well-adherent, and therefore are of little value. In plating baths, when the article reduces the metal of the bath upon itself it is said to produce a local action. In such cases the deposit which may be made by electricity will not be coherent. For instance, iron is electro-positive to copper in an electrolyte of copper sulphate; it reduces some of that copper upon itself; it cannot receive an adherent deposit in such a solution. So, when iron is to be copper-plated it must receive somewhat of a copper coating in an electrolyte in which iron is not electro-positive to copper. Such an electrolyte is found in copper cyanide. As soon as it has received a slight coating, enough to cover it from access of copper sulphate to the iron, it is usually removed to a copper sulphate bath, which is cheaper in constitution and more easily worked than in the cyanide bath.

In depositing some metals, notably gold, brass, nickel, etc., the deposit of metal is not the equivalent of the amount dissolved from the anode. In such cases, gases are evolved from the electrodes. When gases are evolved more electrical energy is necessarily expended than would otherwise be necessary, and the metal deposited is not the true equivalent due to the quantity of electricity used. But the metal deposited and the hydrogen evolved are, together, the equivalent due to the current used.

Of course I cannot well, in the limits of a single lecture, more than glance at the principles involved, as I bring to your attention some experiments which serve only to point to the practice of the art.

The electrotyper's bath is in principle the same as that used by the electro-plater. I have here some elegant specimens of his art, and will call your attention specially to some typical ones, and try to give you a general idea of how they are made.

A few years ago, all of the electro-plating and electro-typing of the country was done by electricity, generated by galvanic batteries. Now, except in the very small way, all electro-plating and electro-typing is done by the use of dynamo-electric machines. The improvements in these machines have been great in a short time. The first dynamo tried for electro-plating by the Elkintons, the great silver-platers of Birmingham, wore its commutator springs out in 20 minutes, and comparatively little of the energy applied to its running was returned as electricity, and the machine was laid aside in a short time, as giving too much trouble and expense. Two or three years ago much trouble was caused to platers by reversal of direction of the current from the machines at times, so that the deposit which had been made was dissolved from the true cathode and deposited upon what should be the anode. This reversal came from the so-called "polarization" of the solution. This polarization takes place in imperfectly working electrolytes, and in others in which the affinities of the metal of the bath and hydrogen are approximately the same. If hydrogen be deposited on the cathode, or if oxygen forms per-oxides on the anode, the cathode and anode become more strongly positive and negative than natural under normal conditions, so that, on stopping the dynamo, a current of electricity comes in the reverse direction from the bath, and, flowing through the field-magnet coils of the dynamo, magnetize it in the opposite, so that when again started it gives rise to a current of electricity having a direction opposite to that which proceeded from the dynamo in the first instance. Various instruments called "polarity protectors" were devised to automatically break the circuit to the dynamo whenever a return current from the bath was about to flow. But these were not infallible; and oftentimes plated work was ruined before the fact of an existing return current was discovered. But now the recent "shunt wound" dynamos avoid this difficulty effectually.

By the batteries for each 108 lbs. of silver, or each 31·75 lbs. of copper deposited, 32 lbs. of zinc were used in each battery cell, besides a large percentage of waste and the expenditure of an equivalent quantity of acid in dissolving the zinc. Much care and trouble attended the use of batteries. They varied much in power during their use, becoming much weaker soon after starting to work. Dynamos have, with the minimum of care, constant power under constant speed of running.

No wonder, then, that the art of electro-metallurgy has taken a new start, and is receiving a much more extended application than before, considering the ease and economy with which reliable currents of electricity can be generated.

Within a few years after the discoveries of Daniell, Jacobi, Spencer and others, to which I referred in the early part of this lecture, many applications of the new art to industrial uses were proposed. So that we have little that is absolutely new in the suggestions and principles of the art. But it is only since the introduction of the practicable dynamo that we may say we have been able to practice extensively the the broad art of electro-metallurgy.

Here is an electrotype of a page of *The Electrical World*, the weekly journal of electricity which you have seen printed within the walls of the Exhibition Building on a press which is operated by a Daft electric-motor. There is not time to enter into a full description of the process of making this electrotype. Suffice it to say that after the form of type is made up, a mould of wax is made of the face of the type; the surface of the wax is made conductive, and the mould is made the cathode in a bath of copper sulphate solution, in which a copper plate is the anode. Copper is dissolved from the plate and deposited on the face of the wax until of sufficient thickness to be removed from the wax. It then receives a backing of type-metal, cast on the reverse side of the electrically formed copper sheet.

Following the general plan I have just set forth, it is possible to reproduce in copper or other metals fac-similes of many metallic works of art, such as coins, medals, panels, placques, statues and the like. Large articles may be electro-plated with metals for their beautification, preservation, etc. It was, even, early proposed to copper-plate ships electrolytically instead of by the ordinary way. This scheme, so wild in the days of expensive galvanic batteries, may yet be realized in these days of cheap dynamos. No matter now what may be the size of the article to be plated or reproduced in external fac-simile, it may be done if a bath large enough to hold it be at hand. Large cast iron statues are covered with copper or bronze, and lamp-posts, doors, etc., are decorated or imitated.

I have here a large number of electrotypes, kindly loaned me for the purposes of this lecture by Mr. Edward Weston and by the Excelsior Electric Co., whose exhibits attract so much attention in the main building. Here are medalions, ferns, flowers, surfaces showing the grain of wood and leather and the fibre of cloth, and here are specimens of various kinds of laces. All these are from the original artiste production or from nature. Bugs, butterflies, flowers, leaves, fruit and various things too numerous to mention may be covered with copper and then electro-gilt or electro-silvered for ornamental and other uses. A wax form of any object may be made and then coppered and gilded for use. In fact the uses of the art are too numerous to mention, and as useful as they are numerous.

Some of these plates have been made for the purpose of impressing their surfaces on paper or other material in imitation of leather or other materials. Many of the fancy papers and muslins used in bookbinding have their beautiful designs stamped upon them by dies made in this way.

I have seen the pieces of stained glass pictures fastened together by electrically depositing copper in the spaces between the pieces, in place of being fastened together by the weaker and more clumsy lead heretofore used. The dark lines, so well known in such pictures, are thus made narrower and less unsightly, while stronger and therefore better. I might go on enumerating until the subject became tiresome; but enough has been said to show the importance of this art in the older lines.

The great present use of the art is in the production of pure metals in processes of separating metals from one another and from various other impurities. In all alloys and admixtures of metals, not useful as such in the arts, the metals less in quantity than the main one of the mixture may be considered impurities, even though they be gold and silver, until they have been made available in the arts by separation from the other constituents of the mixture. Furthermore, there are waste metals which are worthless because of admixture, but which, if separated from each other, are valuable as before. For instance, tin and iron of waste tin plate. Thousands of tons of this waste made yearly may be made valuable by separation, which can be done electrolytically. There are forty tons of tin on a thousand tons of this waste, worth $32,000, besides $10,000 to $15,000 for the iron. A continuously-working apparatus has been used to carry the waste into and out of a bath containing an electrolyte which dissolves and deposits tin alone, leaving the iron free from tin. The so-called galvanized iron, which is iron covered with zinc, may be separated from the zinc in a similar manner.

One of the great industries of the day, fast spreading in the metal-centres of the world, is the purification of metals, and their separation from one another, so that they may be of industrial value, by the means provided in the art of electro-metallurgy. For instance, impure copper has been so treated by the Elkintons, the great electro-plating house of which I have spoken, in the neighborhood of Swansea, in Wales, for several years. Now there are several establishments on the continent of Europe, and two or three in America, where impure copper is refined by electrolysis.

In a few words, the process is as follows, though some slight modifications in the minor details are in vogue. Copper ores are smelted under the usual concentration-smelting processes until brought to the state of purification from iron and sulphur in which it is known as "black copper." This black copper contains somewhat over 90 per cent. of copper, some sulphur, some iron, antimony, etc.; but, as a rule, the valuable impurities are gold and silver.

The black copper is cast from the furnace, in which it is produced, into moulds, so as to assume the form of plates of about one inch in thickness, or less. These plates are suspended as anodes in a bath containing an electrolyte consisting of a solution of copper sulphate. Other plates of very thin sheet copper are also suspended in the bath, but as cathodes. These anodes and cathodes are alternated in relation to each other, so that each two cathodes have an anode between them, and *vice versa*. Their faces are placed parallel and about an inch apart. A current of electricity causes the dissolution of the anodes and the deposition of copper upon the cathodes until the anodes are almost all dissolved. I have here one of these cathodes. It has received a beautiful and thick coating of copper. It is now exceeding half an inch in thickness. It was originally less than one-sixty-fourth of an inch thick. This is *pure* copper, such as the electrician delights in, when his wires and coils are made of it; for its electrical resistance is at the minimum. An abundance of such copper is very desirable to the electrician because the value of his instruments made from it is much increased over those made of the finest commercial copper to be obtained.

This plate, and others shown at the exhibit of the Excelsior Electric Co., in the main building, were produced at the works of the New Jersey Smelting and Refining Co., at Newark, by a dynamo similar to that shown at their exhibit. I have not time to enter into a full consideration of the process in this lecture. In fact, to do so, would make a long lecture in itself. Therefore I must only glance at its main features. Suppose, that besides the main constituent, copper, the anodes contained sulphur, iron, zinc, lead, gold and silver. The zinc, iron and lead are electro-positive to copper, while the sulphur, gold and silver are electro-negative to that metal. Therefore, zinc, iron and lead will displace copper from the electrolyte as fast as they come to the action of the liquid from the removal of the copper during solution. Therefore, if enough of these metals be, during the process, brought into the solution the copper of the electrolyte would be finally all displaced by them. Therefore, the electrolyte gradually becomes more and more impure until, finally, they entirely supplant the copper, for if the current is properly regulated for the purpose of producing pure copper none of these metals are deposited from the electrolyte, no matter how much of them it may contain.

The "properly regulated current" I refer to, is one in which the difference of potential, of which I have spoken, between the electrodes, is below that due to the difference in the values of the affinities of those metals and copper for oxygen and sulphuric acid. Lead, however, though it displaces copper, does not enter into solution in the electrolyte, because the lead sulphate so formed is insoluble therein. So, from time to time, the electrolyte must be purified by processes not necessary to consider here, or made anew.

But the gold, silver, sulphur, antimony, etc., being more electro-negative than copper are not changed, are not dissolved. They remain in their metallic state, but appear on the surface of the anodes as a fine black powder.

When the anodes are nearly dissolved the cathodes are removed and the pure copper thereon is made into suitable commercial shapes by ordinary metallurgical processes. The anode scraps are carefully washed to save the precious residues, and then remelted with more black copper to be again cast into shape for treatment. The residues together with such of the powder as may have fallen from the anodes to the bottom of the baths, are melted with suitable fluxes to produce bars of gold and silver. These bars are then taken to the Government mints or assay offices for separation, coinage, etc. It is probable that this final separation may be yet performed electrolytically, as it is now done in some private establishments, after analogous methods to those I have described.

One of the yearly products of this country is about 140,000 tons of an impure lead, technically called "lead base-bullion." This base-bullion contains, exceeding 90 per cent., on the average, of lead, and from 50 to 500 or more ounces of silver per ton, with oftimes some gold, besides iron, copper, antimony, arsenic, sulphur, etc.

An establishment for the electrolytic separation of these metals, by a process devised by myself, was recently described in *The Electrical World*. The description is a copy of a paper read by me before the American Institute of Electrical Engineers.

I have here samples of the products of the process in its various stages. Here is a pig of base-bullion. It looks like an ordinary pig of lead. It weighs 100 pounds and contains 125 ounces of silver to the ton, besides about ½ ounce of gold. Here are some of the plates cast from the bullion preparatory to treatment, so as to make them into anodes having an extended surface compared to their weight. I have no cathode here. Each one is a very large sheet of thin brass.

Here is a large bottle containing some of the pure lead such as is deposited on the brass cathodes. You will see that the lead is crystalline; something like the lead crystals shown in some of our experiments. You will also notice that the crystals are in a liquid. That liquid is some of the electrolyte. The electrolyte is a solution of lead sulphate in a solution of sodium acetate. You will notice the brilliant faces of the crystals. They will remain thus brilliant for a long time. I have some now kept in the same manner, under the electrolyte, for six years, and they are as bright as ever. This shows that there is no action of the electrolyte of itself on the lead. But when a current of electricity is supplied as in electrolysis the lead is readily dissolved by it.

I have here a muslin bag which is of a size to receive one of these anode plates; and here is one of the plates in a bag. These bags are useful for these reasons: The pure lead is deposited on the cathodes in a crystalline form, and these crystals either drop off, or are swept from time to time from the cathodes to the bottom of the bath. Now, if the residual impurities were allowed equal freedom to drop to the bottom of the bath the separation would be useless. So a bag is provided to retain the residues so that they may not mechanically mix with the purified lead. In the copper separation such a provision is not necessary, because the copper is deposited on the cathode in an adherent and coherent form.

After the anodes have been dissolved the lead crystals are removed from the baths, and the residues from the bags are separately and suitably treated for commercial purposes.

The principles of this process of refining lead are, that the oxide or sulphate of lead formed at the anodes shall be dissolved by the electrolyte, and that an exact equivalent of the lead dissolved shall be simultaneously deposited on the cathode. Under these conditions no energy is absorbed by the bath other than that used in causing the electricity to pass through the bath.

But if the compounds formed by electricity at the anode be not dissolved, and no metal be deposited on the cathode, then energy will be absorbed. This energy so absorbed may be given off as electric current under favorable conditions. We would have in a bath so constituted as to insure these latter conditions, a so-called storage battery of electricity. These facts I noted and put into practice in the spring of 1878; and then made a large storage battery on these principles and used it practically.

I have here, on this stand, a strong battery cell, kindly loaned to me for this lecture by the Faure-Sellon-Volckmar Co. It consists essentially of lead anodes and lead cathodes immersed in an electrolyte consisting of dilute sulphuric acid. Exactly what takes place, chemically speaking, in a storage battery, authorities differ about. Therefore I will only say that when electric current is passed to a storage battery something is decomposed for which no equivalent composition is made. Therefore, as we have seen, energy must be absorbed; and when the proper circuits are provided the materials so separated by the decomposition recombine, and in so doing give up the energy they had absorbed electrolytically, as electricity.

As may be deduced from the facts and principles I have set forth, energy may be stored up, so to say, by electricity, in baths of various materials, wherever the energies of combination at the anode and cathode differ. This field of research is barely discovered, and thorough exploration of it may lead to the discovery of valuable facts for use.

The phenomenon called polarization, to which I have referred, belongs to this field. Polarization is to be avoided in the electric transferrence of metals, for its existence necessitates the expenditure of costly energy. It may be avoided in some measure, and in many instances almost entirely, if the electrolyte be properly constituted, by keeping the molecules of the substances which take part in the operation in constantly appropriate relation to one another. The electro-negative constituent of the electrolyte must be in constant contact with the electro-positive anode; and the electro-positive constituent of the electrolyte must be in constant contact with the electro-negative cathode. Otherwise, other and improper constituents take part in the operation and energy will be absorbed or uselessly expended. To avoid this condition, which takes place when the electrolyte is motionless, owing to the decrease of the amount of the proper constituents at the electrodes due to the action itself, a constant circulation of the electrolyte must be kept up; and the more rapid this is the greater the speed of the electrolysis, or the less the strength of the electrolyte requires to be.

But I see that my allotted time has been much exceeded and therefore I must bring my remarks rapidly to a close. I have been able only to glance at some of the principles and practices of this great art which may be said to be scarcely in its infancy. As I contemplate its future I see in this great means of producing and utilizing a form of energy which we call electricity, a great aid not only to the metallurgist but to the chemist in his researches and analyses. We have seen that by its aid we determine the affinities of one material for another. We may compose and decompose many compound substances. The chemist's art is but this. I see that he can produce his metals and his salts by this action, and in many cases much more cheaply than by the various processes of substitution he now employs. And before many years we will not only see extensive electro-metallurgical establishments for the production and working of metals, but we will also see, side by side with them, their legitimate branches, electro-chemical establishments for the production of chemicals, dye-stuffs, etc.

But a short time ago it would not pay to do these things by the expenditure of zinc and acid. Now the grandest concrete production of the physicist, the dynamo-electric machine, furnishes us with means for conserving energy to industrial purposes, marvellously, effectually and cheaply. I thank you for your kind attention.

JAPANESE COLONY IN GERMANY.—Some Berlin capitalists are about establishing, near that city, a Japanese colony of forty workmen and their families, in accordance with the plans of a Japanese architect. There will be workmen in metals and in lacquer, ceramists, painters, enamelers, silk weavers, etc., all working according to the methods of their native land. The public will be admitted to study the various processes employed by the workmen.—*La Nature*, May 31, 1884. C.

THE DIVINING-ROD.

By Rossiter W. Raymond, Ph.D., New York City.

[A lecture delivered at the International Electrical Exhibition, September 18, 1884.]

(Concluded from page 18.)

I condense from M. Chevreul's book the following list of the principal authors on the subject, for the period now under consideration.

Dr. Chauvin of Lyons (a letter to the Marquise de Senozan, dated September 22, 1692, published in the brochure *Superstitions anciennies et modernes,* Amsterdam, 1733; also in an appendix to the 2d edition of Lebrun's *Histoire critique des pratiques superstitieuses*).

Dr. Pierre Garnier of Lyons (a letter to M. de Sève, published November 10, 1692, at Lyons). This, like the letter of Dr. Chauvin advanced the corpuscular hypothesis.

Two anonymous letters concerning the divining-rod, published in the *Mercure* of January and February, 1693. The first combats the corpuscular hypothesis; the second argues that, although this explanation is to be rejected, there is, nevertheless, nothing supernatural, magical or diabolic about the phenomena, and that they are probably to be referred to physical causes as yet unknown.

M. de Couriers, a blind man and thorough partisan of the divining-rod (a letter in the *Mercure* of March, 1693).

M. L. de Vallemont, priest and doctor of theology (*Physique occulte, ou Traité de la baguette divinatoire et de son utilité pour la découverte des sources d'eau, des minières, des trésors cachés, des voleurs et des meurtriers fugitifs,* Paris, 1693, 12mo. 608 pp.). The argument of this book has been summarized above. Its purpose was to diminish the category of "occult" things by showing that the phenomena of the rod, like those of magnetism and electricity, were explicable by the physical corpuscular hypothesis.

Two letters published in the *Mercure* for April, 1693, by order of the Prince de Condé. One is anonymous; the other is addressed by M. Robert, *procureur du roi,* to Father de Chevigny. These are the documents which record the failures of Aymar; and the second concludes as follows: "His Serene Highness desires the assurance to be given to undeceive the public, that the rod of J. Aymar is nothing but an allusion and a chimerical invention. These are the Prince's words."

Father Lebrun (*Lettres qui découvrent l'illusion des philosophes sur la* *baguettes, et qui dêtruisent leurs systèmes,* Paris, 1693; also *Histoire critique des pratiques superstitieuses qui ont seduit les peuples et embarrassé les savants,* Rouen and Paris, 1702). These publications have been alluded to above. The letters comprise an interesting correspondence among Father Lebrun and three of the foremost *savans* of France, Father Malebranche, the abbé de Rancé (the celebrated abbé de la Trappe), and the abbé Pirot, chancellor of the University of Paris. Lebrun (writing before the Lyons murders) narrates the alleged powers and performances of the diviners of Dauphiny, and asks Malebranche what he thinks of the matter. The latter, reasoning acutely on the data offered, decides that, as to physical objects (*e. q.* springs) if the action of the rod is real, water on the surface must agitate it more powerfully than water underground, also that it cannot be possible by any natural law to distinguish between the action of a small spring near the surface and a larger spring lying deeper. As to moral effects (discovery of murderers, missing landmarks, etc.), he concludes that if the rod really does this without fraud, it can only be from a supernatural cause (presumably demoniac) and that the use of the rod is therefore to be condemned. Lebrun rejoins, agreeing with this view as to the moral effects, but suggesting the corpuscular hypothesis as to material objects. A second letter of Malebranche declines to yield this point, and positively ascribes the whole thing to the devil. Meanwhile, the abbé de la Trappe consulted by Malebranche, and (like the latter) assuming for the sake of the argument, but not accepting fully the reality of the phenomena, says the discovery of murderers, etc., must be ascribed to Satan, but the physical effects may be the result of a physical cause. Nevertheless, the use of the divining-rod should be discouraged altogether on religious grounds. Chancellor Pirot takes the same position, saying that the curés should forbid this practice as unlawful.

In his *Histoire Critique,* Father Lebrun gives a large number of instances in which the divining-rod has failed. He cites the provost of the Isle of France, who testified that he had often employed experts with the rod, both to detect criminals and to discover springs, and had never found one in whose hands the instrument was not "often variable and very often false." He shows the fundamental contradiction between two schools of practitioners, one of which declared that touching the rod with the same substance as the hidden substance which was causing it to move, would stop the motion; while the other declared that this proceeding augmented the motion. The conclusion of the argument is, that the phenomena of the rod (which Father Lebrun appears to believe are sometimes free from conscious imposture) are due to an intelligent cause of some kind, and that this cause must be satanic.

Father Ménestrier (*Indications de la baguette pour découvrie les sources d'eau, les métaux cachés, les vols, les bornes déplacées, les assasésinats*, etc., published at the end of the author's *Philosophie des images énigmatiques*, Lyons, 1694). This author takes the same view as the preceding.

M. Baritel (*La Verge de Jacob, lou 'art de trouver des trésors*, 1693). The translation of this book by Thomas Welton has been already mentioned. The author appears to hold the corpuscular theory of the abbé Vallemont, with the addition (which I do not find in any of the views of Vallemont's book), that he ascribes the capacity of different men in the use of the rod to the effect of the planets under which they were born, and defines this effect to consist in opening the pores of some more than others, and filling some more than others with "active particles," which being crowded out through the aforesaid open pores by the intrusion of exterior particles (from springs, metals, murderers, stolen goods, boundary lines, etc.,) powerfully affect the rod. Whoever has from his favorable stars both particles and pores galore, can discover with the rod anything he reasonably seeks. But he who has "only plentitude of particles with closed pores," will be sensitive to certain things only, to wit, such as move him most strongly, because the particles emanating from them violently eject *his* interior particles in spite of his less abundantly perforated epidermis.

The condemnation expressed by so many ecclesiastical authorities and by the Inquisition (October 26, 1701) undoubtedly checked the use of the divining-rod for moral purposes. At least we hear little of such applications in the eighteenth century. But believers in the rod were still numerous, and practitioners abounded, particularly in Dauphiny. The discoveries of Galvani put into the hands of the crude science of the day the materials for a new hypothesis, which was first applied to the so-called hydroscopes or water-diviners. One of the most celebrated of these, Bartholemy Bleton, was born in Dauphiny in 1750, and in 1780 was called to Lorraine by Dr. Thouvenel, who wished to study a good specimen of this art. The doctor, like his predecessors a hundred years before, tried credulous experiments and asked questions in abun dance, and obtained a mass of supposed facts, out of which he immediately made a book, published in 1781, and called *Mémoire physique et medicinal montrant des rapports évidents entre les phénomènes de la baguette divinatoire du magnetisme et de l'électricité.* It would be useless to give the voluminous details of his investigation. The following points are, however, especially noteworthy. In the first place, Bleton apparently did not profess to discover immaterial qualities or facts, but chiefly confined himself to the detection of running water. In the second place, he frankly avowed that the rod possessed no power in itself by virtue of its form or material, and that it was merely an index, outwardly exhibiting to the spectators his inward feeling. This feeling the doctor declared to be a tremor, attacking first the diaphragm and communicating itself through the body and hands to the rod. In the third place this tremor was found by Dr. Thouvenel to be weakened, though not destroyed, when Bleton was on a tree or ladder or another person's shoulder, instead of the ground, or when he touched electrified substances; but the tremor and also the movement of the rod were completely stopped when Bleton was insulated from the ground. Upon facts of this kind he based his electrical theory. I remark, by the way, that the observations and the theory of Mr. Latimer, in his recent work on the divining-rod, already mentioned, recall in a striking manner the performances of Bleton and the theory of Thouvenel. Mr. Latimer claims to have made the new discovery that the effect of the divining-rod is destroyed by insulating the practitioner, as for instance, by placing him upon a platform supported by glass bottles. If he had known how thoroughly this claim had been examined and refuted, almost exactly one hundred years ago, he would have had less faith in its novelty and value.

Thouvenel's book made no little sensation, and in 1782 Bleton was called to Paris, where a remarkable series of experimental tests were applied to him. A newspaper report of the day declares that in the presence of many thousands of spectators he followed a subterranean aqueduct in the garden of the Luxemburg for fifteen thousand yards without a mistake. The chief engineer of the water-works is reported to have said that the trace was so accurate, that if the maps of his office had been lost, Bleton's foot-steps would have constituted a complete survey to replace them. It is just possible that the *Journal de Paris* was tempted to make a sensation of this case, and it is also quite possible that a keen observer might notice indications other than those of his own diaphragm, by which he could follow the line of buried pipes. A large number of experiments, more calmly reported, certainly do not sustain the enthusiasm of this account. It was found, for instance, that Bleton often passed over running water, when blindfold, without noticing it; and that when taken several times over the same course he would not point out accurately each time the spots which he had previously marked. For example, of sixteen points once indicated, he recognized with the rod on the second round but eight and missed the other eight. A single point to which he was repeatedly brought blindfold, he indicated three times and missed three times. Of seven channels of running water which he was made to cross repeatedly, he indicated one once in four times, another once in four times, and another once in three times, while still another, which he crossed in two spots, affected his diaphragm at one crossing, and not at all at the other. The insulation experiment was repeated by a physician at Paris. As a point where Bleton's rod was powerfully affected by alleged subterranean water, he was mounted upon a stool with glass legs, and immediately the rod ceased to be affected. When the stool was removed, however, and he stood upon the ground, the rod resumed its sensitiveness. But Dr. Charles, who conducted this experiment, took occasion, while Bleton stood upon the stool, to bring the top, without his knowledge, into electrical communication with the earth by means of a good conductor, thus destroying the insulation completely, though the hydroscopist supposed it still to exist. Under these circumstances, the rod remained inactive, and the destruction of insulation did not produce the slightest result. This was declared at the time to be a proof of Bleton's charlatanry; but, as we shall see hereafter, it is equally consistent with the hypothesis of unconscious mental and muscular action.

As a final test of Bleton's capacity as a hydroscopist, he was taken blindfold into the new church of Saint Genevieve, where there was known to be no water for one hundred feet below the floor, the vaults, foundations, etc., actually extending all that distance below. Here he professed to discover at numerous points large and small streams of water. Thouvenel subsequently asserted that his *protagé* had been affected by currents of damp air circulating in the cellar, but this explanation was universally considered as a desperate attempt to maintain a theory already brought into discredit by experimental tests. Bleton, however, though he ceased to be seriously respected by impartial scientists, continued to receive much attention, and to do a thriving business, both in Paris and subsequently in the provinces. Here, however, he no longer worked blindfold or professed to see with his diaphragm. He proceeded, like the ordinary water-diviners, with open eyes, studying all the natural indications, and coming to his decisions with abundant leisure; and under these circumstances it is beyond doubt that he rendered many valuable services to landed proprietors by successfully locating wells. In many cases, however, he failed entirely, and it is reported that even in those in which he succeeded, he was seldom right as to the depth at which water would be found or the quantity which would be obtained. It should be mentioned that in Dauphiny, where Bleton discovered a large number of springs, he was regarded with an esteem never given to Aymar and some other famous hydroscopists. In other words, the people who knew most about the art of discovering water, pronounced Bleton to be a real expert, while they believed Aymar and Prarangue (of whom a word presently) to be more or less charlatans. A review of all the facts leaves little doubt that in Bleton's case there was an unusually large proportion of the skill of the prospector, combined with rather less than usual of the mysterious claims of the wizard.

Concerning Jean Jacques Parangue, mentioned above, it will be sufficient to say that he was born in 1760, near Marseilles, was said to have been peculiarly sensitive as a child to the presence of subterranean waters, and became famous as a hydroscopist; but he used no rod at all, and the scientific theory advanced by his friends was one of clairvoyance. His eyes were described as very peculiar, and it was asserted that he saw water through rocks, earth or masonry, but, strangely enough, not through wood, crystal or glass. Like Bleton, he often deceived himself as to the volume and depths of the springs he discovered.

Dr. Thouvenel never saw Parangue, but defended him against the incredulity of the physicists and undertook to show that the phenomena of clairvoyance even was merely a case under his electrical theory. According to his explanation the delecate nerves of the eyes were affected by the electrical currents traversing the body, and therefore the clairvoyant really experienced the sensation of vision by an internal, not an external excitation. Those who have read the admirable treatise of the late Dr. Clarke upon *Pseudopia* will notice with interest that in this case Dr. Thouvenel, explaining imaginary facts by an untenable hypothesis, nevertheless came very near a true physical theory of visions.

The worthy doctor emigrated at the time of the French Revolution, and carried with him to Italy another Dauphinese hydroscoped named Pennet, whom he exhibited from city to city in support of his electrical theory. Pennet professed to find with his rod not only water, but buried metals and coal. I will not go at any length into the experiments. Some of them were striking and successful, and impressed even such *savans* as Spallanzani, more or less predisposed to expect discoveries in the new domain of animal magnetism. In many other cases, however, the experiments failed. For instance in a trial of three days, at Padua, before a commission of *savans*, Pennet promenaded for two hours on the first day in a garden in which had been buried at different points, four metallic masses and a thousand pounds of coal. He could not find the metals at all, and only after much difficulty indicated the coal. On the second day his ill success was equally marked. Finally, on the third day, of three metallic deposits he failed to find the first, came pretty near the second without exactly hitting it, and found the third. The area covered by the search was only 840 square feet. Upon this test, Spallanzani revoked his favorable opinion. But at Florence, as reported by M. Bilot (*Mélanges scientifiques et litteraires*, 1857, t. ii., p. 80), though I do not know on what authority, Pennet was so completely disgraced as to render worthless all evidence furnished by his career. A walled enclosure was prepared for experiment. It contained ninety small divisions in five of which metals had been hidden. Dr. Thouvenel having discovered that wet weather hindered success, the experiment was delayed until after eight dry fine days, and it was then fixed for the following day. During the night which intervened, Pennet climbed by means of a ladder into the enclosure. A suspicious person who was watching the ground removed the ladder, and whatever the divining-rod could show, it was unable to show the prisoner the way out. This adventure, being made public, destroyed the credit of Pennet at Florence. Dr. Thouvenel could not deny the fatal fact, but, with true loyalty to science, declared that Pennet's moral defects had nothing to do with his physical faculty. It is not only fair to add that no such passage as this is cited from Dr. Thouvenel's works.

Numerous hydroscopes soon appeared in Italy, and a vigorous discussion of the subject followed. One of the latest celebrated experts of this class was Campetti, who was called to Munich in 1806 for scientific examination. One of the writers of this period, the Abbé Amoretti, himself a member of a family containing many hydroscopes, makes the significant assertion that the sensation experienced by the holder of the divining-rod is one of heat or cold. But the name of Amoretti recalls the fact that he was one of those who revived and continued the discussion of "the magic pendulum."

The earliest mention of this apparatus, according to M. Chevreul, is found in the work of Ammianus Marcellinus, the last of the Latin historians, who died A. D. 390. In an obscure passage (lib. xxix., cap. 1), giving the confession of one of the conspirators against the Emperor of the East, this author describes in the words of the conspirator, the ceremonies adopted by the band to discover the name of the Emperor's predestined successor. Among these was the use of a ring suspended by a fine thread over a disk, around the edge of which, at equal intervals, were the letters of the alphabet. The ring in its oscillations pointed out successively the letters T, H, E, O; whereupon, without further continuing the inquiry, all perceived that Theodorus was the one designated by destiny.

Father Schott mentions the pendulum in his *Physica curiosa* (1662), already alluded to in this paper.

In the latter part of the eighteenth century, and at the beginning of the nineteenth, several scientific men were attracted to this phenomenon. Albert Fortis, (*Mémoires pour servir à l'historie naturelle et principalement à l'oryctographie de l'Italie et des pays adjacents,* 1802), Prof. Gerboin of Strasburg (*Recherches expérimentales sur un nouveau mode de l'action électrique,* 1808) and Prof. Ritter of Munich (see his report in the Tübingen *Morgenblatt für gebildete Stände,* No. 26, January 30th, 1807) were among the number, as well as the Abbé Charles Amoretti, librarian at Milan, to whom I have already alluded. As this mention of the pendulum is in the nature of the digression, though (as will appear) not without pertinence to my main argument, I content myself with an abstract from Ritter's article. He says:

"Take a cube of pyrites, native sulphur or any metal. Size and form are indifferent. We may use, for instance, a gold ring. This body is attached to a piece of thread, quarter to half an ell long. This is held pinched between two fingers and suspended vertically, all mechanical movement being hindered. It is best to wet the thread slightly. In this condition, the pendulum is held over or close to a vessel full of water, or over any metal, as a piece of money or a plaque of zinc or copper. The pendulum insensibly assumes elliptical oscillations, which form themselves into a circle, becoming more and more regular. On the north pole of the magnet, the movement is from left to right; over the south pole, from right to left; over copper or silver, as in the former instance, over zinc or water, as in the latter. . . . . Over an orange or an apple, on the side of the stem, the move is the same as over a south pole; on the opposite side, as over the north pole. The same difference in polarity is shown by the two ends of a fresh egg. It shows itself still more strikingly in the different parts of the human body, the head acting upon the pendulum like zinc, the sole of the foot, like copper; forehead and eyes, north pole; nose and mouth south pole; chin like the forehead; and so on, with all parts. The palm and the back of the hand act in opposite senses. The pendulum will move over every point of the finger, and even over the fourth or ring-finger, but, in that case, in an opposite direction. This finger has also the faculty of arresting or diverting the movement of the pendulum. It needs merely to be placed alone upon the table used in the experiment"

So much for the outline of Ritter's statement. He was at this time occupied with Campetti, above mentioned, and naturally he brought together in his thoughts the divining-rod of Campetti with the pendulum of Fortis (Fortis had experimented with it, and it was often called by his name, in consequence; but his death in 1803 deprived Ritter of his advice and aid in further tests).

Competti was a young peasant from the borders of the *Lago di Garda* who had seen the performances of Pennet, Dr. Thouvenel's last *protegé*, and had found himself possessed of similar powers. Not only Ritter, but Schelling and Franz Baader examined him. The opinion expressed by Ritter was that the divining-rod is simply a double pendulum, requiring to set it in motion, a force greater than those which move the pendulum. Ritter wrote this after consultation with Amoretti and others; and after either he or Amoretti had visited and consulted, at Padua, the great Volta.

But Prof. Gerboin carried his scientific study of the pendulum to a much greater extent. His book contains in 356 octavo pages the records of 253 experiments, and a most elaborate theory of "organo-electric force," in its different qualities, expansive, compressive, passive perturbatory and active perturbatory. The simplest actions of these qualities may be indicated thus—to condense from the professor's somewhat verbose description:

By virtue of the *expansive* quality, which resides most abundantly in the thumb and fore-finger, a pendulum held between these two is caused to describe with its centre of gravity a circle. The *compressive* quality, belonging characteristically to the middle finger, will not permit this motion, or will stop it—as when a highly *compressive* man touches the hand of an *expansive* man, which is holding the swinging pendulum. Contact ceasing, the movement recommences. The *passive perturbatory* is a high degree of expansive, and the *active perturbatory* in like manner a powerful *compressive.* The possessor of the former, if, while holding a pendulum he is suitably touched by one of the first or second class, will find the pendulum, if at rest, to start backward; and if in motion already, to reverse its motion. The fourth class is, like the second, negative in its action. Persons exercising either the compressive or the active perturbatory quality cannot cause the pendulum to oscillate; they can only counteract or reverse its oscillations in the hands of others.

Considering that the author goes on to formulate the permutations and combinations of these qualities of force, their relations to the different fingers, and to a long list of organic and inorganic bodies, I may be excused from following further his intricate and obscure system. Elaborate as it is, the whole structure is absolutely baseless; and constitutes a capital example of what St. Paul denominated "science, falsely so called." Its vast array of worthless experiments are merely so many ciphers in a row, with a decimal point instead of a unit at the head. When the distinguished chemist Michel Eugène Chevreul (long the chief of the Gobelin tapestry-works, and the author of a well-known book on Color, as well as other important works) took up the subject in 1812, he was not long in discovering that when the eyes of the operator were blindfolded, so that neither his will nor his thought could consciously or unconsciously affect the movement of the pendulum, the data, arguments and conclusions of Fortis, Amoretti, Ritter and Gerboin, the organo-electric force, with its qualities *expansive, compressive* and *perturbatory;* the south poles and north poles, the classifications of the universe thereby;—in short, the entire science, bag and baggage, disappeared!

Gerboin had pronounced the action of the divining-rod to be a case of *passive perturbatory.* Chevreul, as we shall see, put both the rod and the pendulum in a new category. But before proceeding to state his theory, I will devote a word or two to the evidence presented in our own country.

It is safe to say that most of it, like most of the evidence of the past, is open to the suspicion of at least an alloy of deception. Men who make money out of their reputed skill with the divining-rod and who could not make as much money or advertise themselves so widely if they claimed only a high degree of skill as prospectors, will almost inevitably ascribe to the rod what is due to other means of inquiry; will explain away failures, exaggerate successes, and not establish or execute or permit really thorough and sincere experiment. The most distinguished expert in this art on the Pacific coast has been repeatedly made ridiculous by the result of test experiments. On one occasion, as I learn from an eye witness, who also reported the circumstances to the *Mining and Scientific Press* of San Francisco, this diviner was permitted to inspect a metallurgical laboratory, which always contained a large amount of gold, either in bullion or coin. After this inspection he was brought (blindfold) again into the laboratory, and assured that no coin or bullion had been removed. Under these circumstances he was requested to find the metal with his rod. The coin had all been put in its natural receptacle, the fire-proof safe; and the bullion had been fastened with wire to the under-side of a writing table. The operator found neither of them, though the point of his rod was frequently within an inch of thousands of dollars. He had probably suspected a trick, and he declared that the gold had been removed. When the bandage was again removed from his eyes, and the coin and bullion shown to him, he claimed that his rod had been diverted by the immense amount of treasure in a bank half a block distant! There have also been operators in California claiming to be natural magnets, and not using the rod; but they are not known to have accomplished any better success. One of these natural magnets was employed to trace a lost vein for a mining company at Grass Valley, the mine of which had been at one time the most productive in California. Under his direction the company cut for many hundred feet, at an expense of $30 to $40 per foot, through tough serpentine rock, and found nothing. Not only are these belts of serpentine at Grass Valley well known to be barren in general, but this particular belt was actually exposed in a cross-section, parallel to this expensive underground cross-cut only one-eighth of a mile away. The persons most familiar with the mining districts of the West declare that in Grass Valley, and elsewhere, the divining-rod has accomplished nothing of practical value. It is very recently announced by telegraph from Tombstone, Arizona, that a large body of ore has been found at a considerable depth, under a spot indicated by the "hooda-stick" (which, I suppose, is some sort of divining-rod) in the hands of a common workman. I need hardly say that such a discovery proves nothing. It would be of course presumptuous for me in the absence of information as to persons and circumstances to criticise this most recent case, but I cannot forbear saying that nothing is more common in experience of mining superintendents than the discovery of ore-bodies by workmen, who have carried for a long time the secret knowledge of their existence. Most frequently it occurs when a mine seems to have been exhausted, or at least the superintendent does not know where to look for ore, and finally leases some portion of the ground to miners who, by a good luck that would be surprising if it were not so easily explained, go straightway into a *bonanza*. It is not always, however, the certain knowledge of the existence of an ore-body observed by workmen and kept secret with a view to future profit, which guides these practical explorers. Often it is their great familiarity with the indications of the ground, and sometimes let me add, the ignorance and pride of the manager himself co-operate with this result, by leading him to pursue some erroneous theory of exploration, and to refuse the advice of practical men. The so-called instinct of Mexican miners for finding ore, exhibited particularly in such irregular formations as those of the quicksilver mines of New Almaden, is, indeed, an unconscious practice of an unwritten science.

The scientific explanation of the movement of the divining-rod was given by M. Chevreul, in a letter to M. Ampère, published in 1833 in the *Revue des Deux Mondes*. This letter contained an account of the experiments made by the writer in 1812, more than twenty years before, with the pendulum. Finally, in 1853, M. Chevreul having been appointed by the Academy of Sciences upon a committee to examine a work on the divining-rod, wrote a report on the subject, including the "exploring pendulum" and the then novel wonders of "table-tipping."

This report was published in 1854, under the title *De la Baguette Divinatoire, du Pendule dit Explorateur, et des Tables Tournantes, au*

Point de Vue de l'Histoire, de la Critique et de la Méthode Experimentale. It is worthy of notice that this venerable *savant* is still active at the age of ninety-seven; only the other day, he spoke before the Academy, referring to a paper he had presented to that body, if I remember correctly, seventy years ago!

Chevreul ascribes the movement of the rod, apart from cases of deliberate deception, to minute, unconscious, muscular movements; and these are caused, he thinks, by the imagination or intuitive or unconscious decision or expectation of the operator. An impression that the rod will dip at a certain point, or a wish that it would, or even, in some minds, a fear that it may do so, are all effective causes of the peculiar muscular movement. Stories describing motions of the rod so violent as to strip the bark from it, in spite of the resistance of the holder, do not disprove the above theory. The position of arms, hands and fingers usually prescribed for the holding of the rod, as explained in the beginning of this essay, is one in which it is not easy (though not impossible) to produce by conscious effort the peculiar movement referred to. But it is also one in which skillful effort, if employed, may be easily disguised; and, finally, it is one which invites muscular cramps, and produces muscular torsions and involuntary movements, not to be resisted successfully without a change of position. Under these circumstances a man might easily twist the bark from a willow-stick, and yet fancy he was trying not to do it.

In concluding this survey of the subject, I shall take a somewhat wider view than M. Chevreul, and my remarks, though based on his theory, should not be received as representing it.

From the mass of testimony, good, bad and indifferent, the following propositions may be safely deduced:

1. The material, consecration, astrological relations and ritual formalities of the rod are entirely irrelevant and indifferent to its efficacy. This disposes at a stroke of nine-tenths of the science which the Middle Ages so laboriously accumulated on the subject.

2. The rod itself is entirely inert, unless in the hands of a human operator; and according to the declaration of the most famous experts, such as Aymar, Bleton, Amoretti, and many others, and a whole school of diviners who do not use the rod at all, it is merely an index, revealing and magnifying in visible results the peculiar inward sensations of the diviner.

3. The favorite and most convenient form of the rod (λ) is one which promotes involuntary movements and also permits deception.

4. The involuntary minute musclar movements may proceed either from the causes enumerated by Chevreul, or from a truly and purely physical sensation. To this I will presently recur.

5. The uses of the rod for discovering moral qualities, re-locating missing landmarks, tracing stolen property, prophesying the future, or even (as in the 17th century was the case) selling the orthodoxy of theological dogmas, will not now be seriously defended by any one. They belong to charlatanry and superstition.

5. The agency of demons we may also set aside, as a view outgrown if not disproved. The pious Jesuit Gaspard Schott (1662), who held this view, was, as we have seen, shaken in his faith, though not convinced, by testimony showing how often the rod failed to act, or gave unreliable indications. He half admits that if Satan were at the bottom of it, it should work better. As an instrument of divination, it is unworthy of the devil! But, it might have been rejoined, that, as a means of perplexing and misleading mankind, that distinguished expert could scarcely have improved upon it.

As old Albinus (*Das entlarvte Idol der Wünschelruthe*, 1700) quaintly says:

"Ich achte, dass kein verworrener Ding in der Welt zu finden als das Wünschelruthen-Wesen, denn was Einem recht und tauglich ist, das ist vielen Anderen wieder unrecht und untauglich, dass aus solcher grossen Confusion nicht viel Gutes zu präsumiren ist."

[I ween, that no confoundeder thing is to be found in the world than the divining-rod business; for whatsoever is right and fit according to one, the same is wrong and unfit according to others; until there is no good to be presumed, out of so great confusion.]

7. The application of the rod to the discovery of metals, coal, buried treasures, etc., is shown abundantly to be chimerical. The rules and methods, as well as the asserted performances of its professors, contradict each other; and innumerable failures and exposures have justly covered with ridicule their pretensions.

8. The transparent humbug of locating wells with the rod, to strike oil at depths of from a hundred to thousands of feet, needs no comment. In this case there are positively no signs by which a given *spot* can be selected. The experience of neighbors may show a certain area to be probably productive; and within that area a certain line may be

inferred, sometimes, to be the line of a productive channel. But if a keen observer, having gone so far, professes to select a point on that line, he is simply betting on his luck; and, as carried on in Pennsylvania, the bet is a safe one for the oil-smeller, who gets a handsome fee if he wins, and loses, in the opposite event, nothing but an hour or two of time.

9. The case is somewhat different with the discovery of springs, and (since ore deposits always have been and often still are the channels of springs) of ore-deposits. Here we have much stronger and more abundant evidence in favor of the rod; and here, in my judgment, there is a residuum of scientific value, after making all necessary deductions for exaggeration, self-deception and fraud. Keeping in mind that the rod is merely an index to the minute muscular movement, and that this movement may have a mental or a physical cause, let us consider (putting aside at once all cases of deliberate deception) the following facts:

There is undoubtedly a practical science of discovering mineral deposits and springs. The most skillful prospectors can scarcely explain how they decide upon the place where they dig; and yet, though they are by no means always successful, it is certain that they are more successful than the inexperienced. The books from Agricola down, give rules and signs; but the practical explorer is unacquainted with the books. He has a science of his own, which affects his mind, without conscious reasoning, by the principles of association and memory. He recognizes in a new locality the tokens that he has become accustomed to associate elsewhere with a rich gulch, or an abundance of pay-quartz. Perhaps he never took conscious note of them; yet their recurrence affects his judgment. This practical skill is almost unerring within narrow limits. Under new conditions, it breaks down. Some of the most absurdly foolish gold-mining enterprises I have known, have been set on foot by old California miners, who, returning to their former homes east of the mountains, have said at once of some ravine or hillside, that it was "just the place for gold." In like manner, certain omens and signs from Cornwall have been carried around the world by Cornish miners. But whatever the errors of practical prospectors, the noteworthy point is, that in localities with which they are familiar (or in other localities where the conditions are the same) they come swiftly, surely, and without conscious reasoning, to impressions and decisions. A decision of this kind would probably, in a man of suitable nervous organization, affect the muscles already constrained by holding a divining-rod, and the minute muscular movement or inward sensation might be unconscious.

The case is still plainer with regard to the discovery of springs. Everybody knows that Indians in our desert West can find water where most white men cannot; and the experienced frontiersman has learned the art from the savages. The conformation of the surface, the tracks of animals, above all, the presence or absence of certain plants, are his guides. In regions where the finding of water within a few feet of the surface is a question of life or death, it becomes a science very rapidly. The location of artesian wells is a different matter. Science will do that in a general way; but science will not determine a difference between one spot and another, ten or twenty feet away, the geological and topographical conditions being alike in both; and the selection of one of two such points as better than the other for a deep well, is purely a piece of imagination or deceit. It must be remembered, however, that the diviner has in such a case an easy task. If possessed of sufficient practical judgment to decide that a certain area or line would probably be suitable for boring, he is pretty sure to be safe in selecting any point of it. But this, it will be seen, is very different from the unconscious skill which points out in the dry *arroyo* the very spot where water will be found in half an hour's digging.

In abundantly watered regions like New England, it is perfectly well known that the springs follow under or through the soil and above the bed-rock, more or less defined channels. A well may be dug at one point without success, and a subsequent attempt a few yards away may be successful. The superficial signs of these water-courses are often subtle, and they are little studied by the inhabitants in general. It is not necessary that a farmer, who will want to locate a well once in his lifetime, should know the signs of water, as a ranchman or *vaquero* must know them. Hence, men who are keen observers (in many instances, finding profit in the business), get impressions, amounting to a local science, of the "lay" of the rocks, the general courses of the springs, the differences in surface vegetation, the earlier or later greenness of grass, the presence of particular grasses and shrubs, the ascent of local vapors at sunrise, the behavior of frosts, in short a hundred minute tokens which betray the presence, even at considerable depths, of a water-channel, and the point at which it comes nearest to the surface. The unconscious judgment of such an expert may decide upon a given spot over which he walks; and while he could undoubtedly come to this conclusion without having a rod in his hand, I am willing to admit seriously that the rod may help him make up his mind by emphasizing for him his own slightest tendency to a decision. It should be remembered here that even Bleton, the greatest of all the hydroscopists, generally used to go (if permitted) many times over a piece of land before finally locating a well, and often disregarded the first intimations of the rod. In other words, unless he felt sure, every time he crossed a given spot, that it was a good place to dig, he did not rely upon his first sensation or impression. Moreover, neither he nor any other hydroscope has ever accurately divined, except on an occasional lucky guess, either the distance from the surface or the quantity of a subterranean spring. Yet a very large spring, or one very near the surface, appears to have had, usually, a relatively greater influence upon hydroscopes.

This brings me to the final inquiry, whether there may not be, apart from unconscious skill or judgment, a purely physical effect produced by a subterranean spring upon a person walking over it. Electrical theories on this point were only possible in the days when the laws of electricity were little understood. We know now that the earth is a vast conductor, and that the tension of its currents is consequently so low as to be reckoned as the zero of the electricians' scale; hence, that no perceptible electrical current can leave a particular bit of the earth to pass through a human body and return. For this purpose analogies between rock-contacts or fissure-veins and the voltaic pile are inapplicable.

But the effects of moisture and temperature upon the nerves are often striking; and here, I think, is a matter which writers on the divining-rod have generally overlooked. The distance at which animals will "scent water" is very great. Their faculty is supposed to consist in great sensitiveness to temperature and moisture. The quickness with which some people "catch cold" on the slightest exposure to dampness—particularly of the soles of the feet—is also a familiar phenomenon. Now it is curious that among the most puzzling of the well-authenticated accounts of the divining-rod are related instances in which women, unacquainted with its use, and not expecting it to work in their hands, have found it to dip without their conscious help, over spots previously or subsequently shown to contain springs.

Here I would recall the remark of Amoretti, that the sensation of the diviner is one of heat or cold. These two are not easily distinguishable when minute and transient. What we call a chill includes both. Is it not probable that a single unconscious chill may be the physical result to certain sensitive persons, of walking over a spring of water or a belt of rock or soil kept by running water cooler than the adjacent rock or soil, or a spot of surface made by the same cause damper than the surrounding surface. That these causes exist, is beyond doubt. Thermometrical measurements have not been made; but the way in which grass grows and snow lies and frost settles and vapors rise over springs, is due to the temperature and moisture of the ground in such places. Goethe in one of his novels (*Die Wahlverwandschaften,* I believe), describes a lady as seized with a sudden chill upon a spot where subsequently the outcrop of a coal-bed is discovered. The incident is introduced without attempt at scientific explanation, and apparently to convey to the reader a vivid conception of the lady's extreme delicacy of temperament. I infer from it that such cases were known to the great philosopher, and that he believed such supersensitiveness to be in some way connected with the performances of diviners.

To this then, the rod of Moses, of Jacob, of Mercury, of Circe, of Valentine, of Beausoleil, of Vallemont, of Aymar, of Bleton, of Pennet, of Campitti—even of Mr. Latimer—has come at last. In itself it is nothing. Its claims to virtues derived from Deity, from Satan, from affinities and sympathies, from corpuscular effluvia from electrical currents, from passive perturbatory qualities of organo-electric force, are hopelessly collapsed and discarded. A whole library of learned rubbish about it, which remains to us, furnishes jargon for charlatans, marvelous tales for fools, and amusement for antiquarians, otherwise it is only fit to constitute part of Mr. Caxton's *History of Human Error.* And the sphere of the divining-rod has shrunk with its authority. In one department after another, it has been found useless. Even in the one application left to it with any show of reason, it is nothing unless held in skillful hands, and whoever has the skill may dispense with the rod. It belongs with "the magic pendulum" and "Planchette," among the toys of children. Or if it be worthy the attention of scientific students, it is the students of psychology and biology, not of geology and hydroscopy and the science of ore deposits, who can profitably consider it. For us miners and prospectors, the advise holds good which was given us three hundred years ago by the wise Agricola, the father of our profession, who says the believers in the rod find some veins with it by accident. *"Sed idem multo saepius perdunt operam, et ut venas invenire possint, nihilominus in fossis agendis defatigantur, quam adversae partis metallici."*—"but the same people much more frequently lose their pains, and in order to discover veins have to fatigue themselves with digging, not less than the miners of the opposite school."

As a piece of sorcery, he goes on to say, the virtuous and respectable miner will avoid it; as a piece of science, it is inferior to the study of nature, following the indications of which, the skillful and prudent miner selects a good place for exploration, and *"ibi metallicus agit fossas"*—"there the miner digs"—to which business, rod or no rod, he is bound to come at last.

SPONTANEOUS DECOMPOSITION OF EXPLOSIVE GELATINE.—According to Abel, neither trinitrocellulose nor the less nitrated products are affected, when pure, by a temperature near 100°, but the easy decomposibility of gun cotton, sometimes observed, is due to the presence of nitro-derivatives of foreign organic substances (the incrusting matter of the cellular tissue), which, when heated, quickly decompose with formation of free acid. Prof. Chas. E. Munroe, U. S. N. A., reports the following case which has occurred under his own observation. Some camphorated explosive gelatine was wrapped in paraffine paper, then in light brown Manilla paper, and laid on a shelf. After something more than a years' exposure it was found, in the early winter, to be giving off nitrous fumes and to have shrunk considerably in volume, while the outside of the paper was covered with congeries of fine crystals. The odor of camphor was still quite strong. The mass was immediately put into a vessel of water. It was found to be friable, and, after a short immersion, disintegrated. The camphor odor soon disappeared, and the water became of a straw color, gave a strong acid reaction, and showed traces of nitrous acid, but no nitric acid. On evaporation of the filtered liquid, oxalic acid crystallized out in quantity, and on evaporation of the "mother liquor" on the water-bath, a sugar-like mass was obtained, which gave the glucose reaction with Fehling's solution. The paraffine was regained unchanged, and the paper was recovered, but in a flocculent condition, and with the color bleached from the brown. Careful search failed to reveal the presence of glycerine, nitro-glycerine, or gun-cotton.—*Jour. Amer. Chem. Soc.*, vol. 6, Feb. 1884. C.

A NEW REFRACTORY BRICK.—A French engineer has introduced a refractory brick of pure graphite, by perfectly agglomerating the powder of that substance. It is well known that graphite is nearly infusible at the highest temperatures that can be produced and this new class of bricks will doubtless prove very serviceable in metallurgy, where the want of linings which are wholly infusible has long been felt.—*Gaceta Industrial*, March 25, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

BY PROFESSOR EDWIN J. HOUSTON.

No. 5.—EDISON'S TELEPHONIC INVENTIONS.

It is a significant fact that, of the four men, Bell, Gray, Dolbear and Edison, who have had so much to do with the present condition of the articulating telephone, and whose labors have enabled it, to so great an extent, to occupy its present commercial position, three of them, Bell, Gray and Edison, were for several years previous to its extensive introduction, engaged in active work on different systems of multiplex-harmonic telegraphy.

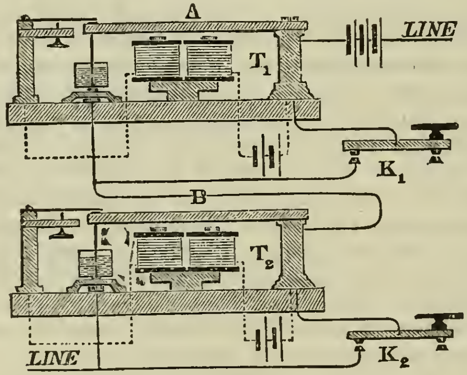

FIG. 1.—Edison's Acoustic Telegraph.

The different systems of multiple telegraphy thus developed, though differing in their details, are all dependent for their operation on the transmission, over the main line, of electrical impulses that are varied at the regularly recurring periods necessary for the reproduction of the pitch of the musical sounds transmitted. The electrical currents sent into the line are simultaneously varied in their intensity by the vibrations of reeds tuned to produce several notes of different pitch. On reaching the distant end of the line the currents, thus superposed on one another, are caused to impart a vibratory motion to tuned electro-magnetic receivers, whose rates of vibration correspond to the rates of vibration of the transmitting instruments. The receiving operator at the distant end of the line, having his instrument sensitive to the signal sent by his correspondent at the transmitting end, is thus unaffected by the signals that are being simultaneously transmitted by the other instruments.

With a knowledge of the results already achieved by Reis in articulate telephony, the mere fact of constantly dealing with such varied electrical currents was naturally enough followed by marked improvements in the articulating telephone.

Edison began his investigations in multiplex-harmonic telegraphy in September, 1875, when he constructed an arrangement whereby two tuning-forks of different rates of vibration, were kept in constant motion by the action of an electro-magnet. A battery electrode, attached as a metallic point to one of the tines of each of the forks, dipped into a vessel containing acidulated water, and during the vibration of the fork, was moved towards and from the other electrode. Under the variations in the resistance thus effected, undulatory currents were sent over the main line. This form of apparatus is shown in Fig. 1.*

In this form of apparatus a local battery is provided for the vibration of the fork and its movable electrode. The movements of this electrode in the liquid, towards and from the metallic point in the bottom of the vessel, vary the otherwise constant electric current in the main battery connected with the line, and thus send an undulatory current over the line. Keys K_1, and K_2, are used for signalling, by the short circuiting they effect. The receiving apparatus for this device is shown in Fig. 2.

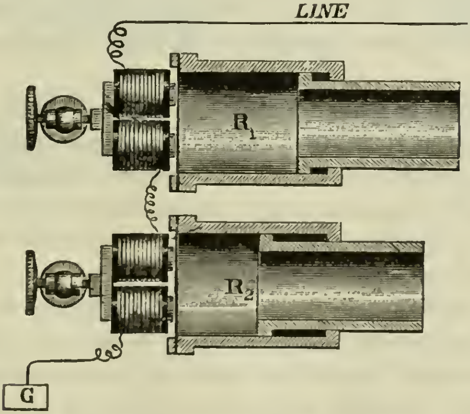

FIG. 2—Edison's Acoustic Telegraph Receiver.

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* The author is indebted for Figs. 1, 2, 9 and 10, to *The Speaking Telephone and Talking Phonograph*, by George B. Prescott.

It consists essentially of the two electro-magnets connected to the main line. Opposite the poles of these magnets are placed two hollow vessels, R_1, and R_2, to the ends of which are soldered iron diaphragms. Although the undulatory currents produced by both transmitting forks, pass through the electro-magnets of each of the receivers, R_1, and R_2, and therefore affect their diaphragms, yet the resonant column of air in each of the receivers, being tuned by means of a sliding or telescopic joint, to vibrate in unison with but one of the sounds, that sound only is heard, to the exclusion of the other. When, therefore, the transmitting keys are operated, the signals, resulting on the starting or the stopping of the vibrations, are heard in their appropriate receivers only, that sent by T_1, being repeated by R_1, only, and that sent by T_2, by R_2, only.

Mr. Edison's early inventions in telephony were mainly in the direction of transmitting instruments of the type that depend for their operation on variations produced by the voice in the electrical resistance of a battery circuit. Any form of electro-magnetic receiving telephone is suitable for use with such transmitters. His first experiments were made with Reis transmitters, to which he applied the method of gradually varying the strength of the current by the introduction of a drop of water between the platinum point and the diaphragm. The receiver used with this transmitter was that shown in Fig. 2. He also modified this form of apparatus by placing several drops of water between two metallic discs. The results obtained with these early forms of apparatus were not quite satisfactory, although articulate speech was obtained.

Edison's carbon telephone forms his most valuable contribution to telephone transmitters, that operate in virtue of variations in the resistance of the circuit. The perfected transmitter was the gradual outgrowth of a great number of what may be termed preparatory inventions. It will be of interest to notice some of these early forms of variable-resistance transmitters.

One of the earliest patented of such transmitters consisted in a number of contact springs, with resistances so included between them as to be short circuited by the movements of the vibrating diaphragm. As the diaphragm vibrated under the influence of the sound waves these resistances were alternately cut out, or introduced into the circuit of a battery. This form of transmitter is shown in section in Fig. 3.

The diaphragm, g, has interposed between it and a flexible conductor, D, an elastic cushion, f, formed of a piece of rubber tube, fastened to the diaphragm. The object of this arrangement is to prevent the setting up of false vibrations.

A number of metallic springs, e^1, e^2, etc., form the terminals of a series of resistance coils. These springs are placed contiguous to the flexible metallic strip D, so that when D, is moved to and fro by the vibrations of the diaphragm it comes into contact with e^1, just a moment before it does with e^2, and so on. When D, touches both e^1, and e^2, the resistance coil included between them is cut out, thus lessening the resistance of the battery circuit. On a more vigorous movement of the diaphragm, the flexible strip D, touching all the contact points, thus cuts all the resistance out of the battery circuit. The strength of the electric waves sent into the line is therefore proportional to the amplitude of the vibration of the diaphragm, or to the loudness of the sound waves.

In Fig. 4, is seen a rear view of the diaphragm, showing the arrangement of the rheostat wires and the mode of winding the same.

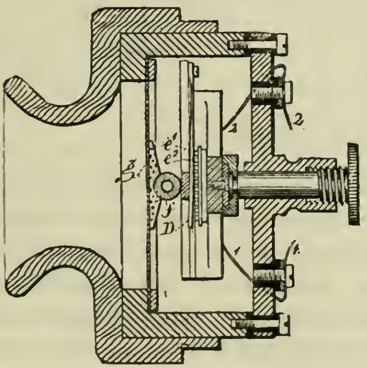

FIG. 3.—Edison's Rheostat Transmitter (Section).

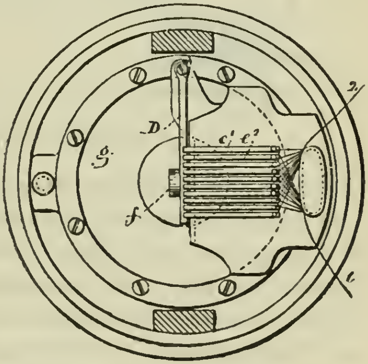

FIG. 4.—Edison's Rheostat Transmitter (Rear View).

Fig. 5, shows the circuit connections; h^1, h^2, h^3, h^4, h^5, etc., are resistances connected to the contact springs e^1, e^2, e^3, e^4, e^5, etc. An induction coil, A, formed, as shown, of the coils m^1, and m^2, has the ends of its secondary coil m^2, connected to the ground and the line. The primary wire m^1, is placed in the circuit of the battery, c, and the resistances h^1, h^2, h^3, h^4, h^5, etc. B, is the receiving instrument, and B^1, its diaphragm armature.

The use of the induction coil, with any form of variable resistance transmitter, marks a great advance in telephony. The maximum variation produced by the voice in the resistance of any transmitter must, necessarily, form a comparatively small portion of the total resistance of the main line with all its instruments. When, therefore, the direct battery circuit is employed on the main line, the variation produced in the strength of the current by the transmitter must necessarily be weak, and the sounds produced by the receiving instrument, at the distant end of the line, correspondingly weak. But when the battery is short circuited, through the variable resistance and the primary of the induction coil, the variations in the resistance produced by the voice are comparatively great, and corresponding variations are sent over the line by means of the induced currents set up in the secondary coil.

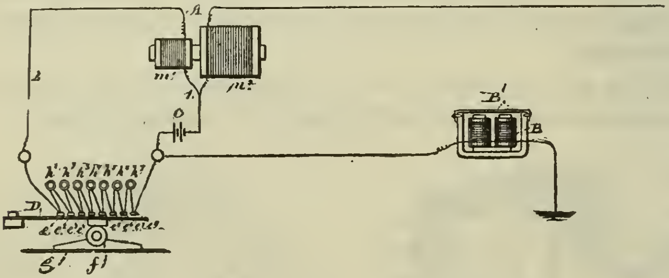

FIG. 5.—Edison's "Secondary" Telephone Circuit.

Then, too, if the resistance of the secondary coil be made comparatively great, the induced current will have a high electro-motive force, and the influence of an increased resistance, due to great length of line, will be much less.. The use of the induction coil may, therefore, be regarded as marking a decided era in telephony. It is scarcely necessary to add, in this connection, that the systems of telephony in general use are greatly dependent for their successful operation on the employment of induction coils.

The uninsulated rheostat-transmitters shown in Figs. 3, and 4, were modified by Edison in a variety of ways. For example the rheostat was given the form of a long, thin, platinum wire, wrapped in a spiral form, around the outside of a cylinder of some insulating material, and so placed that the forward movement of the diaphragm causes the metallic spring to successively short-circuit each convolution of the wire rheostat, thus decreasing the resistance of the circuit.

In another form of rheostat-transmitter, a coil of uninsulated wire is loosely wrapped around a vertical, insulating support, so that the movements of the diaphragm produce a compression or elongation of the spring, and thus throw its successive convolutions into or out of the circuit.

Although articulate speech was obtained by the use of the rheostat-transmitters described above, yet the effects were by no means of a satisfactory character. The variations in the resistance were of too sudden a character. Instead of the resistance being gradually varied by the movements of the transmitting diaphragm, they were thrown in abruptly. The diaphragm would move so as to cut out one of the resistances thus throwing a sudden variation on the circuit. Then no further variation would occur until the diaphragm had reached the next contact point when another sudden variation would occur. It therefore followed that the speech, reproduced by the receiver, was confused and often unintelligible, and quite deficient in either its finer modulations of intensity, or in its quality.

These difficulties were obviated by the invention of what Edison terms his "articulators, or electric tension regulators." These consisted essentially of tufts of fibrous materials, such as asbestos, sponge, cotton, wool, feathers, or silk, coated or covered with a thin layer of any electrical conducting material such as plumbago, metallic powders, etc. A small quantity of any of these materials so prepared, placed loosely together between two rigid plates so as to be compressed by the forward movements of the diaphragm, will gradually, but markedly, vary the electrical resistance of a circuit in which it is placed.

The following description of one of these "articulators" will serve to render the preceding clearer. The fibrous material is preferably elastic, so as to avoid permanent compression during use. For this purpose silk is preferable. The unspun fibre is cut in lengths of say the one-sixteenth of an inch, and coated with plumbago, either by rubbing or otherwise. The fibres are then rolled together with a little loose plumbago in a cigar shape and retained in shape by a few binding fibres of silk.

The fibre rheostat so obtained is then placed at *f*, Fig. 6, between the adjusting post *d*, and the diaphragm *b*. The adjusting post *d*, is provided with a metallic plate *c*, connected to one of the terminals of the circuit. The diaphragm *d*, is made of mica, and is provided with a conducting plate, or spring *e*, which through the conducting spring *a*, connects it with the other pole of the battery. The "articulator" *f*, therefore, is inserted as a variable resistance in the circuit. Any movement of the diaphragm will result in producing considerable variations in the resistance in the circuit due to the variations in the pressure on the bundles of conducting fibre.

Since these variations are due to the number of conducting points on the surface of the fibre that are brought into contact by the increased pressure of the diaphragm, the variations in the resistance must necessarily be of a gradual character, in contradistinction to the abrupt variations effected by the first form of transmitter.

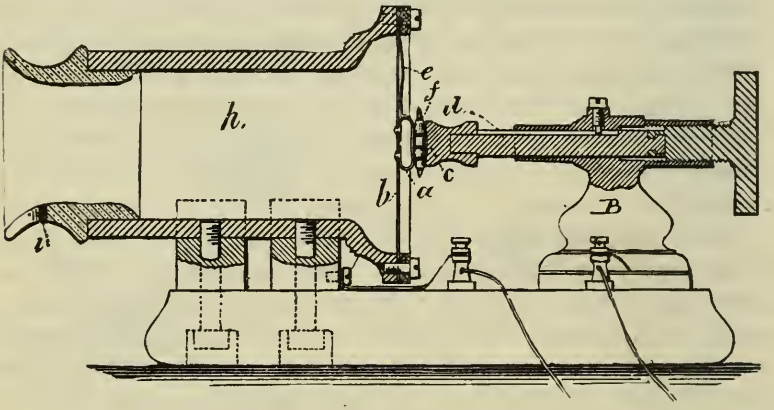

FIG. 6.—Edison's "Fibre Articulator."

The mica diaphragm, first employed for telephones by Edison, possesses, it is claimed, many advantages over the ordinary metallic diaphragm. Its advantages over any of the old forms of membranous diaphragms employed by Reis are evident, since the mica is not as much effected by the moisture of the breath, or by changes of temperature. Its advantages over the metallic diaphragms, are not, however, so apparent, since, being composed of a number of more or less parallel plates of varying thickness and elasticity, it is difficult to see how such a plate could as freely accept the rapidly varying rates of the vibrations of the sound waves, as could a homogeneous, highly elastic, metallic plate of uniform thickness.

The aperture at *i*, in the mouth-piece, is provided so as to avoid the hissing sounds produced by many of the consonants.

From transmitters in which the resistances consisted of elastic non-conducting materials, more or less covered with conducting substances, the step to resistances consisting entirely of conducting substances was but natural. This step led to the invention of Mr. Edison's carbon transmitter, which must be regarded as an extremely valuable contribution to telephony.

Edison tried numerous experiments with variable resistances consisting throughout of solid conducting materials, before he fully demonstrated the valuable properties possessed by carbon in its various conducting forms. One of his earlier forms of carbon telephone is shown in Fig. 7.

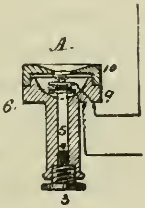

FIG. 7.—Edison's Carbon Transmitting Telephone (Earlier Form).

The cap 10, serves to hold the diaphragm firmly at its edges. A piece of cork or rubber tube is secured to the middle of the diaphragm. This tube is adjusted so as to rest against an ivory disc, provided on its outer face with a platinum disc. An adjustable rod, 5, is also provided at its upper end with a platinum disc. Between these two platinum discs is placed the carbon rheostat, which in this case is composed of a button of lamp-black carbon, 6. The two platinum discs serve as conductors by means of which the carbon rheostat, and the primary wire of an induction coil are included in the circuit of a battery. An adjusting screw, 3, is provided for regulating the pressure on the carbon rheostat.

By numerous experiments Edison found that carbon of high electrical resistance is not as well adapted for a rheostat as is carbon of a higher conducting power, since with very high-resistance-carbon the movements of the diaphragm by the action of the sound waves would not produce the requisite change of resistance. He at first sought to increase the conducting power of the carbon by mixing other substances with it so as to separate its particles, but found that treated in this way its resistance became too great to permit its use in connection with the primary circuit of an induction coil.

Fortunately, however, he discovered that the variety of carbon produced by the imperfect combustion of such light hydrocarbons, as gasoline or naptha, was capable of undergoing considerable changes in its conducting power when submitted to variations of pressure.

The carbon button is prepared as follows, viz.: The darkest portions of the carbon obtained from the soot of burning naptha as before mentioned, is selected, and the mass then subjected to a powerful pressure so as to effect a consolidation. This button is placed in the telephone in the manner shown in connection with Fig 7.

The success attained by Mr. Edison's telephone resulted from the fact that the variations in the resistance of the carbon button under variations of pressure, being dependent entirely on the pressure, varied directly with it. The use of the cork, or rubber disc 8, is intended to prevent the continuance of the vibration of the plate under the action of the voice, after the tone of the voice causing a particular vibration has ceased to act. In this way the distinctness of articulation is very greatly improved.

The use of this rubber tube, however, gave rise to the necessity for continual readjustment due to its gradual change of shape. To avoid this difficulty Edison replaced this rubber tube by a short spiral metallic spring formed of a few turns of stout wire. This modification is shown in section, in Fig. 8.

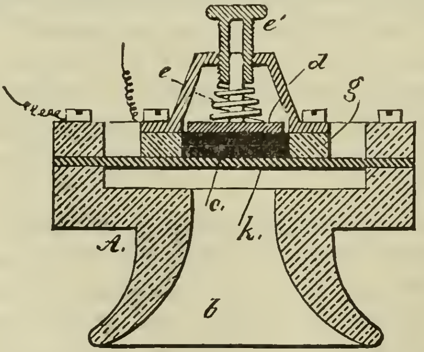

FIG. 8.—Edison's Modified Carbon-Transmitter.

The mouth-piece *b*, is furnished with a stout diaphragm *k*, firmly secured at its edges in the manner shown. The centre of this diaphragm, on which the carbon button, *c*, rests, is platinized in order to ensure a good contact. The button formed of prepared carbon, is placed on the centre of the diaphragm inside a metallic ring *g*, and is surmounted by a metallic plate *d*, held in position against the button by the spring *e*, formed of a few turns of stout wire. The pressure exerted by the spring *e*, against the metallic plate *d*, is regulated by means of the screw *e*. The carbon button *c*, is placed in the circuit of a battery by means of the conducting wires placed on the left side of the figure.

Since the ring *g*, and the circuit regulating devices are supported on the middle of the diaphragm, it is evident that when the diaphragm is set into vibration by the sound waves, the variations in the resistance of the carbon button are influenced by the inertia of the ring and the circuit regulating devices.

This form of instrument was found in practice to possess a disadvantage, owing to the fact that the tendency of the spring to a definite rate of vibration caused it to produce a musical note that interfered with the distinctness of the articulation. It was in his attempt to remedy this defect that Edison was led to the discovery of a principle of great importance to the successful use of the carbon telephone.

Attempting to avoid the musical note emitted by the spring, he made it of thicker and thicker wire, when he found the clearness of the articulation to become greater and greater. This showed that the increase in the inelasticity of the spring had no effect on the articulation. He inferred, therefore, that since the springs were unnecessary, the action of a transmitter did not require the sound waves to produce an actual vibration of the diaphragms. When the sound waves struck the diaphragm they produced a direct variation of pressure thereon, and thus varied the resistance. He used diaphragms, therefore, that were so thick that the loudest sounds produced no sensible vibrations therein, and fastened the carbon disc and plate tightly together. By these means very excellent results were obtained.

The effects produced by variations of pressure on the conductivity of carbon are well shown by means of the apparatus seen in connection with Fig. 9. The circuit of the battery cell *B*, has inserted in it a galvanometer *G*, and a carbon button *C*. The circuit being closed, the needle of the galvanometer showed a certain deflection. If, now,

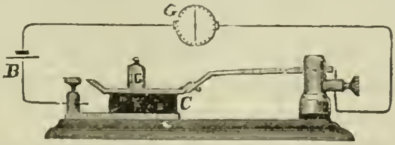

FIG. 9.—Experimental Apparatus.

the weight G, be placed on the carbon in the position shown, the needle of the galvanometer is at once deflected by a more powerful current, thus showing that the resistance of the circuit has been decreased by the increase of pressure. A further addition of weights results in a a greater decrease in the resistance of the circuit.

Edison was aware of and had practically applied the principle of the variable resistance of carbon with variation of pressure, long before he applied it to the construction of his carbon telephone transmitter. For example, as early as 1873, he invented his form of carbon rheostat. This instrument was devised in order to supply an artificial resistance in cable experiments. It consisted essentially of finely divided carbon contained in a glass tube. The carbon varied in resistance with the pressure to which it was subjected. The carbon rheostat does not appear to have been very successful, owing, doubtless, to the fact that its resistance varied greatly with the expansions and contractions of the enclosing glass tubes. It was also varied in resistance by sudden jars or even noises.

Edison has applied the principle of the variation of carbon under pressure to a variety of other uses. Some of these applications were made prior to the invention of the telephone. His micro-tasimeter for measuring radiant heat is one of the most ingenious of these applications. A carbon resistance is included in the circuit of a battery and a galvanometer. The expansion of a metallic rod or bar, by the action of the heat, varies the resistance of the circuit and thereby affects the needle of a delicate galvanometer. This instrument is exceedingly sensitive to very slight variations in temperature and has been employed in some refined investigations. Unless very carefully managed, however, its indications are unreliable, owing to the accidental variations in the resistance of the carbon.

What Edison terms his odorscope is a somewhat similar apparatus. It is designed, we are informed, to electrically detect the presence of various odors. A carbon resistance is, as before, included in the circuit of a battery and a galvanometer. The carbon, and means for varying the resistance of the same, are placed in a partially closed vessel where they are exposed to the action of the effluvia, or odor, that is to be detected, and a motion is observed in the needle of the galvanometer. This motion, it need scarcely be added, is not, in all probability, to be attributed to any molecular action due to the effluvia or odorous particles on the carbon resistance, or on the metals or other substances that are connected therewith, but rather to pressures resulting either from variations in the temperature, or from contraction or expansion consequent on the changes in the hygrometric condition of the absorbent materials.

Another application more directly in the line of telephone inventions is a telephonic repeater. This form of apparatus is shown in connection with Fig. 10.

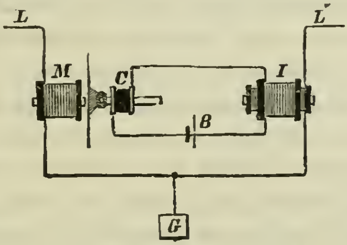

Fig. 10.—Edison's Telephone Repeater.

The local battery *B*, has included in its circuit the primary wire of an induction coil *I*, and a carbon resistance *C*, which acts as the transmitter. This resistance is so connected with the plate of iron opposite the electro-magnet *M*, that it responds to any variations in the strength of the current flowing through the coils of *M*, connected with the main line. When, therefore, a current, which has been varied by the voice of a speaker at a distant transmitter, traverses the coils of *M*, it produces variations in the resistance of *C*, that cause an exactly similarly varied current to flow over the line connected with the secondary coil of the induction coil *I*.

Another application of the same principle is seen in Edison's pressure relay for telegraphic use, invented in 1873, in which the variations in the conducting power of carbon, under variations of pressure, are used to automatically transfer signals from one circuit to another.

Edison has also employed this property of carbon to construct a rheostat, or carbon resistance, that is capable of being greatly varied in resistance with variations in pressure. This rheostat is not, however, very reliable as an instrument of precision, owing to the fact that the carbon does not regain its former resistance on the relief of the pressure.

In the employment of carbon as the variable resistance in telephone transmitters, Edison has obtained the variations of pressure by the action of the sound-waves in a variety of ways. Besides those we have already pointed out, he has contrived a transmitter in which the motion of the diaphragm, under the action of the sound-waves, effects an increase in the resistance of the circuit when the diaphragm moves inwards, and a decrease when it moves outwards under the influence of its elasticity. This he effects by supporting the carbon button between metallic cups connected with uprights secured to the middle of the diaphragm. The inward motion of the diaphragm, on the impact of the sound-waves, causes the uprights to move apart and thus lessen the pressure on the carbons. The movement of the arms in the opposite direction of course increases the pressure on the carbon button.

In addition to telephonic transmitters in which the carbon resistance is placed in one mass between two plates that are urged to and fro by the action of the voice, Edison constructed a number of devices in which two carbon buttons are moved over each other by the sound-waves, and thus vary the electric resistance by reason of the greater or less intimacy of the contact, or by reason of the number of points thus brought into contact. This form of telephonic transmitter was termed by him the "micro-telephone," on account of its ability of responding to much feebler sounds than the other transmitting instruments. This form of transmitter was, in fact, a form of "microphone transmitter." The U. S. Patent descriptive of this modification of transmitter was filed on the 11th of November, 1878.

Edison's micro-telephone is shown in section, in Fig. 11.

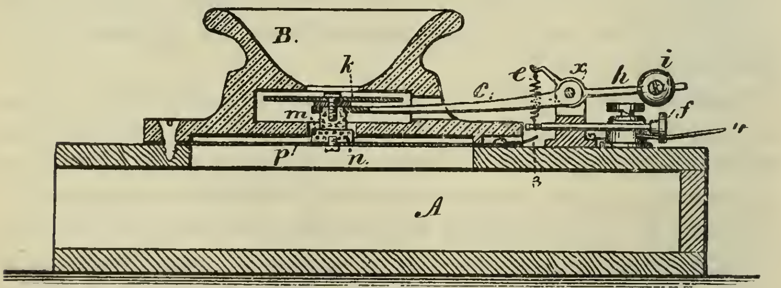

FIG. 11.—Edison's Micro-telephone.

The apparatus is mounted in a hollow, resonant box, *A*, and consists of a mouth-piece, *B*, furnished with two diaphragms *p*, and *k*.

The diaphragm *p*, is placed over a circular opening, in the resonant box *A* ; upon this diaphragm is placed a piece of compressed carbon *n*, and a second piece of carbon *m*, secured to a lever *c*, pivoted at *x*, is placed on the carbon *n*. The arm *h*, of this lever, is provided with a movable weight *i*, intended to counterpoise the weight of *c*, and its connected parts. The spring *e*, serves to vary the pressure of the carbon buttons, *m*, and *n*, on each other. The diaphragm *p*, is securely attached at its edges to the resonant box. The diaphragm *k*, which consists of some light material, like mica, is free at its edges, and is connected by means of a screw to the end of the lever *c*, and placed below the mouth-piece *B*, in the position shown. The arrangement of the circuit is better shown in the plan of the same apparatus in Fig. 12.

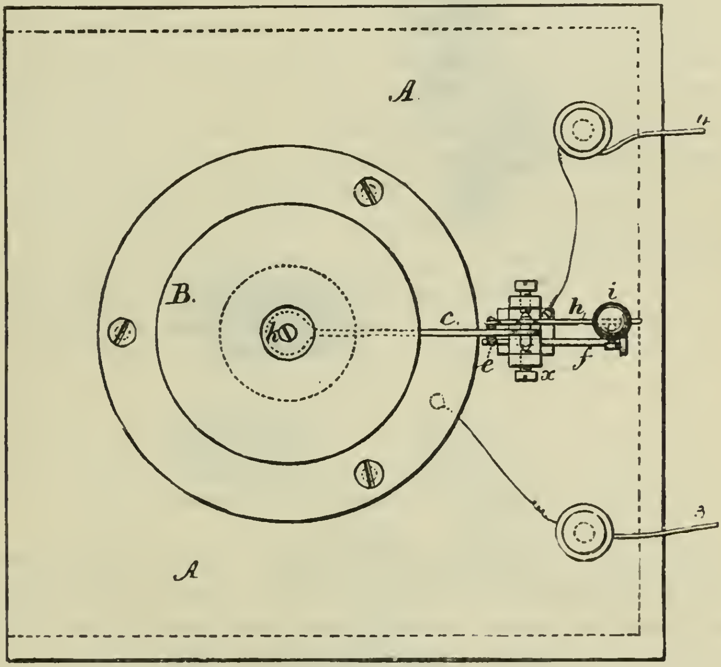

Fig. 12.—Edison's Micro-telephone (Plan.)

The terminals 3, and 4, of a battery are connected respectively to the lower and upper carbon, by being attached to the edges of the metallic diaphragm *p*, and to the arm of the lever *c*.

Exceedingly slight jars or vibrations given to this apparatus, such as by a person walking across the room in which it is placed, or by the sound waves produced by the voice of a distant speaker, vary the current sufficiently to reproduce the voice of a speaker in a suitable receiving instrument.

A modified form of microphone transmitter invented after the preceding is shown in Fig. 13.

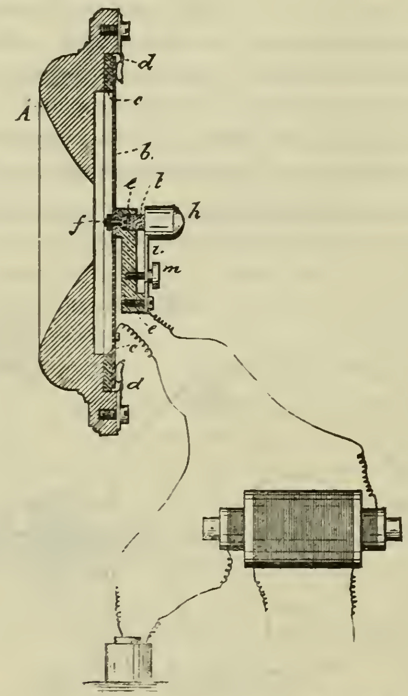

FIG. 13.—Edison's Carbon Transmitter (Microphone Form.)

In this form of apparatus, a mouth-piece *A*, of the usual shape, is provided with a metallic diaphragm *b*, which, instead of being rigidly fixed at its edges, rests on an india rubber ring *c*, and is kept in contact therewith by means of suitably arranged spring fingers *d*. In order to avoid a grating sound by the rubbing of the diaphragm against the metallic spring fingers, the latter are covered with rubber.

There is attached to the centre of the diaphragm by means of a metallic screw *f*, a block *e*, *e*, of insulating material. This block is recessed opposite the screw attachment, for the reception of a button *l*, of hard carbon, or plumbago. A weight *h*, supported on a spring-arm *i*, has one of its surfaces in contact with the carbon button as shown. This surface is platinized in order to ensure a good contact.

The circuit connections are apparent from an inspection of the drawing. The circuit of the battery cell is completed by means of the conducting wires through .the carbon button *l*, and the primary of an induction coil.

The operation of this form of transmitter is evidently dependent on the difference in the pressure against the carbon, which is produced from the inertia of the weight *h*, acting as a resistance to the free movement of the diaphragm.

Edison devised a curious form of transmitting instrument, which he patented in 1882. This transmitter consists substantially of a surface or of surfaces ruled with fine lines that are close together, preferrably several thousand to the inch. These lines, which are parallel to one another, cross the surface in two systems that intersect each other at right angles. The surface of the striated plate is thus cut into a great number of fine points. When surfaces so prepared, are included in the circuit of a battery, and suitably combined with the diaphragm, the motions produced by the sound waves, causing a greater or less intimacy of contact, or a greater or smaller number of points in contact, produce electrical undulations in the current capable of reproducing articulate speech in a suitable receiving instrument.

A transmitter, constructed on this principle, is shown in Fig. 14.

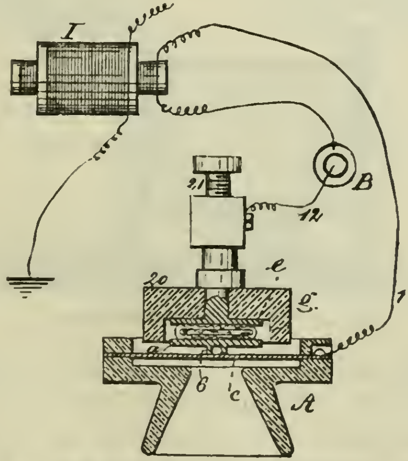

Fig. 14.—Edison's Striated-surface Transmitter.

The mouth-piece *A*, is provided with a metallic diaphragm of the usual construction. The striated surface, which in this case consists of a strip of platinum, scored by fine lines as above described, is folded in a flat form with a piece of felt or rubber within the fold, and the scored surfaces placed in contact with the plates *a*, and *e*. The plate *a*, rests on a short section of rubber tube 6, supported at the centre of the diaphragm. The plate *e*, is connected with the adjusting screw 21, provided for the purpose of regulating the pressure between the surfaces in contact.

The scored platinum foil is therefore placed in the circuit of the battery *B*, and the primary wire of the induction coil *I*, by means of the conducting wires 12, and 1, as shown. It replaces the carbon button of his earlier carbon transmitter, and operates to produce a change in the conducting form of the battery circuit in a somewhat analogous manner.

Since Edison employed a movable electrode in water for varying the current in a line, as early as 1873, in connection with his system of acoustic transmission, it is quite natural to find that he was one of the first to apply the principle to the operation of a transmitting instrument for a telephone, as soon as the telephone became generally known. He devised quite a number of liquid transmitters.

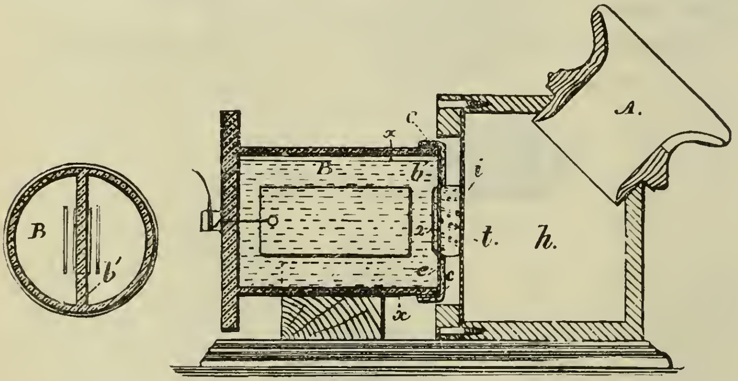

Fig. 15.—Edison's Liquid Transmitter.

In Fig. 15, is shown one of the many forms of liquid transmitters devised by Edison. The instrument is shown in vertical longitudinal section; on the left is a vertical section on the line *x x*.

A mouth-piece *A*, is attached to the hollow box *h*, which is provided with a rigidly attached diaphragm *i*, of mica, as shown. *B*, is a cylinder of non-conducting material, divided by b^1, as shown in the vertical section on the left, into two compartments by a non-conducting material. The cylinder *B*, is provided with two electrodes of platinum, carbon or other conducting substances, connected respectively to line and earth. These electrodes project towards the diaphragm *i*, somewhat beyond the vertical non-conducting partition. The diaphragm *i*, has rigidly attached to its face, a piece of cork *t*, which projects inwards through a slot in the end of the cylinder *B*, and when in position leaves a small space at 2, which limits the passage of currents between the electrodes.

When the sound waves fall on the mica diaphragm *i*, the passage 2, is alternately decreased and increased as the cork *t*, is moved towards or from the electrode, and the resistance of the battery being thus varied, electrical undulations are thrown on the line.

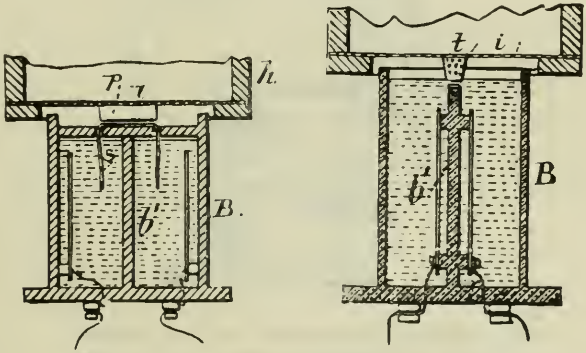

FIG. 16.—Forms of Edison's Liquid Transmitter.

Other forms of liquid transmitters are shown in Fig. 16. On the right is shown a form similar to that described in connection with Fig. 15. In this case the cylinder *B*, is vertical, the conducting liquid space between the cork *t*, and the electrodes is more clearly shown. The division of the cylinder *B*, into two separate compartments by the non-conducting partition b^1, is also more clearly shown.

On the left is seen a device in which the partition b^1, completely closes the two compartments. In this case electrical communication is established between the electrodes by means of a conducting wire *s*, that is moved into or out of the liquid by the vibrations of the diaphragm. The liquid in *B*, may be acidulated water, or mercury.

One of Mr. Edison's most valuable contributions to telephony is to be found in his loud-speaking telephone. This instrument is based on the principle of his motograph, which he patented in the United States on January 19, 1875. By the application of this principle to the telegraph, he was enabled to produce motions in distant telegraphic apparatus, independently of electro-magnetism, or of the motion of galvanometer needles.

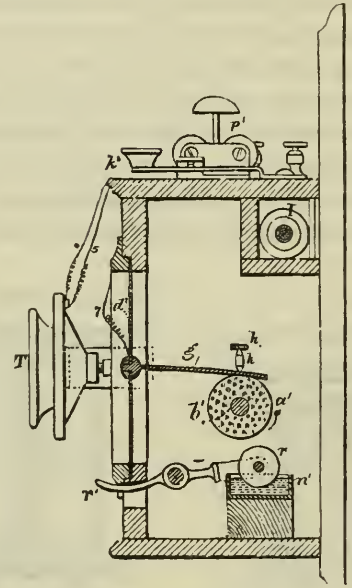

FIG. 17.—Edison's Motographic Telephone Receiver.

The principles of the motograph are well explained by Edison in United States Patent, 158,787, as follows: "The principles of its operation are that, when a moving surface is in contact with a slightly-yielding substance, the tendency is to move the latter by and with the former. If the circumstances of contact are varied, the adhesion of the surface will be sufficient to cause the moving surface to move the yielding substance, or else to cause the yielding substance to slip more freely, and by its spring go in the opposite direction to the moving surface. I have discovered that the passage of electricity through the surfaces in contact will change the frictional adhesion, making it more or less, according to the substances employed; and by balancing the chemical forces so that when the surfaces in contact are not electrified the moving surface carries with it the yielding surface, and when electrified the yielding surface slips back over the moving surface, and *vice versa*, a mechanical movement is produced that is dependent on the electrical condition of the surfaces in contact; hence mechanical motion is obtained, first one way and then the other, that is as unlimited in its speed as the pulsations of electricity that pass, unobstructed by magnets, or other hindrances, over the telegraphic line."

Edison describes in this patent a telegraphic instrument capable of being operated by means of the Morse system, in which the variations in friction obtained as above described are utilized.

Fully aware of the ability of an electrical current to vary the friction between two surfaces, and thus reproduce mechanical motions at the distant end of a telegraph line, it is quite natural that he should at an early date in his telephonic investigations, turn his attention to the motograph principle in connection with systems of telephonic communication. This work resulted in the invention of his loud-speaking telephone, which he patented in the United States on November 25, 1879.

Edison's Motographic Telephone is shown in section in Fig. 17.

In this form of apparatus he utilizes the variations in the friction of a metallic rod on a rotating chalk cylinder. The cylinder a^1, is of compressed chalk, soaked in some electrolyzable solution, such as caustic potash. The shaft b^1, is rotated by means of the handle *f*, shown in a back view of the same apparatus in Fig. 18.

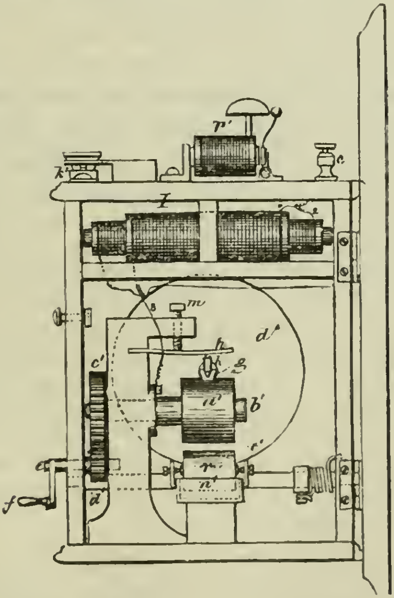

FIG. 18—Edison's Motographic Telephone Receiver. (Back View).

Of course, the chalk cylinder may be rotated by clockwork, or by any other suitable means.

A flat, metallic spring *g*, attached at one end to the centre of the diaphragm d^2, rests on the surface of the chalk cylinder. The pressure of this spring against the cylinder is regulated by means of the screw *h*. In Fig. 19, a plan of this receiver is shown.

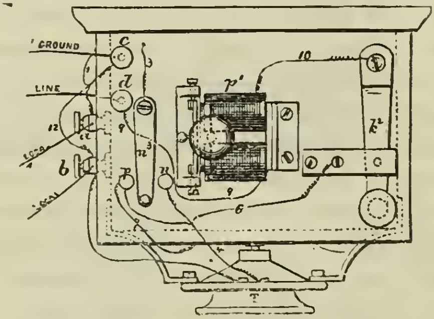

Fig. 19.—Motographic-Receiver. (Plan).

"The line-wire is connected to the spring *g*, while the earth-wire is connected to the shaft on which the cylinder a^1, is secured. If, now, the cylinder be rotated in the direction shown by the arrow and no current passes, the normal friction of the spring *g*, upon the surface of the cylinder a^1, will be very great, and the spring will be carried forward in the direction of the rotation of the cylinder, thus pulling inwardly the diaphragm d^2. If, now, a current passes, whose direction is such that hydrogen will be produced upon the surface of the spring *g*, in contact with the chalk, the friction will be reduced to an extent proportionate to the strength of the current; hence the diaphragm will regain its natural position and continue there as long as the current passes. If, now, the current ceases, the normal friction at once is re-established, and the friction increases, and the diaphragm is violently pulled inwardly again. If, now, a current in the opposite direction is transmitted, the effect is hardly noticeable, as the evolution of oxygen on the surface of the spring *g*, does not, except with a few saturations, decrease the friction like hydrogen, but on the contrary, generally tends to increase the normal friction."

Mr. Edison found that better results were obtained when a constant current was permitted to circulate on the line. He has also found that quite a number of different electrolytes may be employed to saturate the chalk cylinder. The acetate of mercury, mixed with caustic soda, is one of the best. In order to readily moisten the surface of the chalk cylinder the vessel u^1, is provided freely with water. The lever r^1, moves a felt wheel r, against the chalk when the latter has become too dry.

The sound-waves impinging against the transmitter T, which contains the ordinary carbon button, varies the current of a battery, that passes through the primary of an induction coil I, and thus produces positive and negative waves in its secondary coil, which passing over the line cause variations in the adhesion of a metallic strip to a rotating chalk cylinder, similar to that shown at a^1, and g, and therefore cause motions, in its diaphragm that reproduce the speaker's voice.

Since the resistance of the spring and the chalk are greater when the chalk is at rest, than when in motion, the chalk cylinder and its opposing spring may, if so desired, be employed as a transmitter in the place of the carbon transmitter.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, December 15, 1884.

GLOBULAR LIGHTNING.—Gaston Planté described, some years ago, under the name of "Walking electric spark," a peculiar phenomenon produced by the passage of an electric current of high tension. The appearances are so analogous to those of globular lightning, that he considers that phenomenon as a slow and partial discharge of the electricity from storm clouds, when that electricity is exceptionally abundant, and when the cloud itself, or the column of strongly electrified damp air, which forms its electrode, so to speak, almost reaches the ground, or is only separated from it by a thin layer of insulating air. Under these circumstances the ponderable matter which is traversed by the electric current collects under the form of a globe of fire. It is a kind of electric egg, without a glass envelope, which is formed by the rarefied and incandescent elements of air and vapor. The globe is not fulminating and dangerous by itself, for a breath is often sufficient to displace it or even cause it momentarily to disappear. Its presence however is formidable, for it brings the electricity from the storm cloud and reveals the chosen path of its escape. If the layer of air which separates the cloud from the ground is not traversed, the globe of fire may disappear without report. If a portion of the storm cloud approaches the earth or another conductor, the lightning may strike at a distance at the same moment that the globe disappears. If the layer of air is pierced, there is a flash of lightning accompanied by thunder, which is not due to the small quantity of electricity enclosed in the globe, but to the sudden discharge of a large portion of the electricity of the cloud.—*Comptes Rendus*, Aug. 11, 1884. C.

ANNUAL SUMMARY OF ENGINEERING AND INDUSTRIAL PROGRESS—1884.*

THE SECRETARY:—In accordance with my custom at the first meeting of the new year, I beg to ask your attention to the following brief summary of the most noteworthy facts in the fields of engineering, mechanics and technology associated with the year 1884.

The statements given to the public during the past year of the condition of the work on the Panáma Intéroceanic Canal, and the prospects of its completion, were, as usual, of the most conflicting character. For reasons which it will be unnecessary to repeat, this project has never commanded the sympathy of Americans, on which account probably, unfavorable impressions and reports respecting it have found freer circulation in the newspapers than those of an opposite character. An impartial analysis of the facts at my command, justifies the statement that, in respect to the financial support of the enterprise, and the perfection of its engineering organization, and in the extent of the work actually accomplished, the Panama canal is in a fair way to be successfully completed within a reasonable period. The facts brought out in the last published annual report of the Count de Lesseps, and in the excellent *resumé* of Mr. Charles Colné, Secretary of the American company, presented in a paper read before this Institute, bringing down the statistics of the enterprise to September 1, 1884, leave no room for doubt on these points. From these data, it appears that over $100,000,000 have already been subscribed for the shares of the company, of which $25,000,0000, have already been expended in a needful preliminary work and in excavations. The line has been divided into sections, each of which has been, or will be, given out on contract. The total of excavations reported to September 1, 1884, was 10,224,882 cubic yards. This bears a small ratio to the total amount necessary to complete the canal—namely, 156,000,000; but it must be remembered that in a work of such magnitude as this, the preliminary steps are invariably the most difficult, expensive and tedious of execution. The fallacy of estimating the time required to finish the work, on the basis of that already accomplished, will appear from an inspection of the following data of work done during successive periods:

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* From the Report of the Secretary, Wednesday, January 21, 1885.

	Cubic yds.
Work done previous to January 1, 1884	3,610,778
Work done in the first four months of 1884	3,217,460
Work done in the first eight months of 1883	6,614,104

From these figures, it appears that the work of actual excavation accomplished during the first eight months of 1884 was nearly double in amount to that excavated during the previous four years of work on the Isthmus. The argument of the opponents of the Panama canal, that after all these years "only one-thirteenth of the excavation is done," is thus seen to have no bearing whatever as a guide in estimating the possible time and cost of completing the work.

The transmittal by the President of the United States, to the Senate, of the project of a treaty between this government and that of Nicaragua, by the terms of which the United States is given the right to open across Nicaraguan territory an inter-oceanic canal that shall be under the exclusive control of the United States, again directed attention to the Nicaraguan canal project ,which has always been a favorite one with our government engineers. Pending the consideration of the treaty, the government has sent an expedition, under the direction of Mr. A. G. Menocal, U. S. N., to make a re-survey of the location on which the estimates of former surveys of the route, may be revised and verified.

The Nicaraguan canal, as projected, will be 172 miles in length, of which 119 miles will be furnished by lakes and rivers in which there is already sufficient depth of water, or in which such depth can be easily obtained. The probable cost is estimated to be about $60,000,00 or about one-half the cost of the Panama canal, as estimated by Commander Gorringe. The cost of the improvement of the harbors at the termini, however, which will be necessary, is probably not included in this estimate. The Nicaragua route has the advantage, it will be observed, of permitting the utilization of a natural water-way for about two-thirds of its length, It has the additional advantage of being about 800 miles further north than the Panama route. It has the disadvantage of being over four times as long as the Panama route and of requiring a complicated system of locks, of which about fifteen will be needed, and the failure or injury of any one of which would obstruct the entire line. The time required for the passage of vessels will be three days, as compared with as many hours by the Panama sea-level canal. In view of these unfavorable circumstances, and notwithstanding the incontestible advantages of location, it has been, and is yet, a mooted question if such a canal could compete successfully for the world's traffic with a sea-level canal at some other point on the Isthmus.

The ship railway which Captain Eads has proposed to build across the Isthmus of Tehuantepec, about 800 miles further north than Nicaragua, has continued to attract attention, both at home and abroad. The project is unquestionably more favorably estimated, now that its features are better understood, than when it was first proposed. So far from being visionary or chimerical, the plans of Captain Eads are now generally admitted to be entirely practicable, and it is quite within the range of possibility that they may be realized.

The facilities of the Suez canal have of late been taxed to their utmost to accommodate the constantly increasing traffic passing through it, and in consequence of the frequent and expensive delays often experienced by vessels, it was found necessary last year to appoint a technical commission to determine upon the expediency of one or the other of the two measures of relief that are proposed—namely, to build a second canal, or to widen the existing one. This commission has just reported in favor of the last named proposition.

The cutting of a canal across the Isthmus of Corinth, which was begun in the year 1882 by a French company under contract with the Government of Greece, has been steadily progressing. The total length of the canal will be 6,933 yards (about four miles). At the present rate of progress the work will be completed in 1886. This work has some historical interest attached to it, inasmuch as the remains of ancient excavations pointing to early attempts to cut through this barrier between the Black and Adriatic Seas, are still plainly discernible. The canal will have the same width as that at Suez (75 feet) and will shorten the voyage from the Adriatic Sea to Turkey and Asia Minor by 185 miles.

From time to time reports have appeared of substantial progress of the work of draining the Florida everglades, which has been carried on for some years by a company of Philadelphia capitalists, though at this time no statistics of the work accomplished are at hand.

Of considerable engineering and commercial importance is the final completion and opening to traffic of the Arlburg railway. This enterprise was undertaken by the Austrian government, for the purpose of providing a more direct line of communication with Switzerland, and incidentally with France and Western Europe, independent of Germany. The route of the railway is from Innsbruck, through the Tyrolean Alps to the Lake of Constance; and, in connection with the Swiss railways, it forms the most direct route between Austria (and Southeastern Europe generally) and Southern France. The line presented some exceedingly difficult engineering problems, of which the most notable was the great tunnel of the Arlberg, the third in point of length in the world. Work on this tunnel was commenced in June, 1880, and it was pierced in November, 1883. The rapidity with which the work was completed affords a notable example of the advances that have been made in the art of tunneling. Of other important works under construction, may be mentioned the Railway Tunnel, under the Severn river. This tunnel, which was begun in 1873 under the sanction of the British Parliament by the Great Western Railway Company, will, when finished provide uninterrupted railway communication between England and South Wales. The tunnel will be 7,664 yards (about $4\frac{1}{3}$ miles) long. The works were flooded by an accident in 1879, but since that time considerable progress has been made, and at present the tunnel is rapidly approaching completion.

Since January, 1883, work has been in progress upon the great steel cantilever bridge across the Firth of Forth in Scotland, to take the place of that blown down by a storm some years before. This structure, when completed, will be one of the most notable of its kind in the world. It will have a total length of one and a half miles, and of its 22 spans there will be two of 1,700 feet each. There will be in the piers abcut 120,000 cubic yards of masonry, and in the superstructure 45,000 tons of steel. This great structure is being built under contract for £1,600,000.

The railway interests of the United States were among the principal sufferers by the industrial depression which existed throughout the past year, a fact which is abundantly proved by the great falling off in earnings, the enormous depreciation in values which railway securities of all kinds have suffered, and by the financial disaster that has overtaken so many railway companies during the year. The severe economy which the railway companies were forced to practice, is perhaps made most apparent by the large decrease in the mileage of new railway completed during the past year. On the authority of the *Railroad Gazette*, the miles of railway completed during the last seven years were:

1878.	1879.	1880.	1881.	1882.	1883.	1884.
2,916	4,570	7,174	9,789	11,506	6,753	4,350

The total mileage completed at the close of each of the last seven years, was, on the same authority:

1878.	1879.	1880.	1881.	1882.	1883.	1884.
81,774	86,497	93,454	103,242	114,838	121,592	125,942

The construction of 1884 is estimated, but will approximate closely to the true figures. Discounting the probable small error, my informant is sure that the new mileage of 1884 was much less than that of any year since 1879, when railway construction had but begun to feel the effects of the industrial revival. "Since 1879," remarks the *Gazette*, "the increase has been 39,445 miles, or 45½ per cent.; and here we have a sufficient explanation of anything that may be unsatisfactory in the present condition of railroad business."

The cable system of street car propulsion has received a noteworthy extension during the past year, by the construction of about ten miles of such railway for several of the leading street railway companies in Philadelphia, and which was about ready to be put in operation at the close of 1884. It is in contemplation to considerably extend these lines, and if the plans at present decided on are carried out, there will shortly be no less than twenty miles of cable railway in operation in this city. The system in question is in successful operation in San Francisco, Chicago, Detroit and Kansas City.

In the fields of electrics, several subjects of interest may be noticed. The persistent agitation of the question of underground wires has caused the enactment of mandatory ordinances in a number of the principal cities of the country, requiring the wires to be placed under ground after a certain date. Thus far, however, no solution of the question seems to have been proposed which would meet the requirements of the situation in a simple and satisfactory manner to all concerned. With the constant multiplication of the overhead wires in the cities, a period must soon be reached—if, indeed, it has not already been reached in some localities—where the nuisance of maintaining such lines must become intolerable. The present situation seems to be this: While the necessity of placing the wires in the cities, underground, is generally acknowledged to be growing more and more imperative, the problem of introducing the desired reform without imposing serious inconvenience and heavy pecuniary penalties upon the electrical interests, is likewise becoming more difficult to solve. Although some progress in the right direction seems to have been made in

New York, Philadelphia, Chicago, Boston and other cities, in every instance, I believe, it has been found necessary to extend the limit of time in the ordinances above referred to.

Arc lighting seems to be steadily growing in popularity for the illumination of streets, and other large areas. During the past year a careful series of experiments has been made under government direction to determine its practical value for lighthouse purposes; the results, however, do not appear to have been satisfactory in respect of economy. The incandescent lamp, also, has fully demonstrated its value as a means of interior lighting, and its use is steadily extending.

I regret that I am unable to record any substantial advance in the construction or efficiency of the storage battery, through which alone, as many believe, the general introduction of electric lighting, as a practical competitor with gas, will be made possible.

Substantial advance appears to have been made in perfecting the working details of the multiplex-synchronous system of telegraphy (referred to in my last year's summary), a line of which has been in operation the greater portion of the past year between Boston and Providence.

The final settlement, in favor of the Bell Company, of the long pending litigation involving the ownership of the telephone, was one of the notable events of the year. The hope is very generally expressed that the removal of this distracting element will have as one of its immediate results the increase and improvement of telephonic facilities. The promise is held out that long-distance telephoning will receive the immediate attention of the Bell Company, and the present year may witness the establishment of telephonic intercourse on a practical basis between a number of the seaboard cities.

In the direction of the electric transmission of power, it does not appear that any notable advance was made during the past year.

Of special interest in this connection was the International Electrical Exhibition, held in Philadelphia in the autumn of 1884, under the auspices of this Institute, and which afforded an excellent opportunity for the illustration of the most recent advances in the applications of electricity.

From the estimates of Mr. Swank, Secretary of the American Iron and Steel Association, I learn that during the past year the domestic demand for all the leading iron and steel masters was less than in 1883. We made less pig iron and bar iron, fewer steel rails, less steel for miscellaneous purposes, and fewer kegs of nails. From the sources of information at his command, the Secretary estimates the production of pig iron in 1884 to have been at least equal to the production in 1880, which was the year of the "boom." The production in that year was 4,295,414 net tons of 2,000 pounds, or 3,835,191 gross tons of 2,240 pounds. This calculation, he thinks, will be found, upon the reception of the full returns, to be substantially accurate. Our imports of pig iron in 1884 declined to 225,000 tons, of which a large percentage was spiegeleisen for the use of our Bessemer works. It is yet too early to draw any reliable conclusions as to the production of Bessemer metal.

The trials of the basic process in this country do not appear to have given the favorable results that were anticipated of its use. For the present, at least, we are advised that the process has been abandoned.

In his summary of the events of the year, Mr. Swank concludes that the year 1884 was a bad year for the American iron trade, rendering necessary a general reduction of wages, the closing of many manufacturing establishments, and a progressive tendency to lower prices. During the year, for the first time, the influence of a new disturbing element began to make itself felt, namely, the competition of Southern pig iron, an influence which undoubtedly assisted in bringing about a reduction in the price of all pig iron; but the most potent causes of this decline were undoubtedly the competition among Northern producers and the general depression in trade.

The fact, however, that the stocks of iron in manufacturers' hands at the close of the year were no greater, if, indeed, they do not fall slightly below the figures of 1883, is a sign of encouragement, in that it shows that the restriction of production has reached its limit, and that the present production is not in excess of the demand. It is worthy of comment, likewise, that notwithstanding the widespread industrial depression for which the past year will be principally remembered, and the stringent economy which the railway companies, the principal consumers of iron and steel products, were forced to practice, the domestic consumption of iron was almost equal to the consumption of both domestic and foreign pig iron in the year 1880, the most remarkable, in the industrial annals of our country, for its productiveness and activity. This fact exhibits most strikingly the rapidity with which the industrial elements of the country are being developed.

The coal production of 1884 probably exceeded 60,000,000 tons, nearly equally divided between anthracite and bituminous.

The utilization upon a large scale of natural gas as fuel for manufacturing and domestic uses, as a substitute for coal, in and about Pittsburgh, is one of the most interesting, and, in respect to its bearing upon the industries, unquestionably the most important event of the past year. Beginning with the successful striking of a powerful vein of natural gas within the limits of the city by Mr. Westinghouse, a large number of wells have been sunk, and in nearly every case with good results. The developments already made render it quite probable that the whole city is underlaid by great gas reservoirs, which require only to be tapped in order to yield gaseous fuel in sufficient quantity to meet all the requirements of that city and vicinity for manufacturing and domestic uses. Already the new fuel has taken the place of coal in many of the leading manufacturing establishments in and near Pittsburg, and it is being rapidly introduced for the heating of buildings. The discovery of these abundant sources of cheap fuel in the city itself has opened a new industrial era in Pittsburgh. Those who know how large an item in the expense account of a manufactory is charged to its coal consumption, will realize the great advantages which the Pittsburgh manufacturers must derive from the possession of unlimited supplies of a fuel, in every respect superior to coal, and at greatly diminished cost.

The subject is exciting the most profound interest in Pittsburgh. A number of companies are engaged in the piping of natural gas from wells to manufacturing establishments and private dwellings. The daily supply at the close of the last year was estimated at 25,000,000 cubic feet. The formation of new companies and the sinking of new wells is going on so industriously that the supply must in a very short time very greatly exceed that quantity.

The cost of the gas at present is said to be 15 cents per 1,000 cubic feet; but it is anticipated that the inevitable competition which must arise, will bring the price down to 5 cents per 1,000 cubic feet. As is the case with all such new developments, the innovation must pass through its speculative period, and there appear to be serious difficulties to overcome in order to safely regulate the supply of a material under the enormous pressure (often 150 to 200 pounds to the square inch) at which the natural gas issues from the wells. But when the speculative craze shall have subsided, and engineering skill shall have provided the necessary mechanical artifices to safely regulate its distribution, the possession of these vast supplies of gaseous fuel must give to Pittsburgh decided advantages in the development of the industries which have already made her famous.

The discovery during the past year of an agent which possesses the remarkable property of producing local insensibility, has placed in the hands of the surgeon another invaluable agent for the alleviation of pain in some of the most severe surgical operations. The agent in question is the active principle of coca (cocaine); and, in the form of the hydrochlorate, an aqueous solution of from 2 to 4 per cent. strength has been found to produce complete insensibility in the delicate membranes of the eye, so that the operations for cataract and other surgical operations upon this sensitive organ, which were formerly attended with exquisite suffering, are now performed without pain. The agent appears to act, though not with the same promptness and certainty as upon the eye, as a local anæsthetic of general applicability.

Referring to my allusion last year to the important bearing of Parteur's experiments in rendering harmless the virus of hydrophobia, it is of interest to note that a commission of savants appointed by the French Academy, has after a careful repetition of Parteur's experiments and study of his methods, fully confirmed his announcement that he had succeeded in rendering dogs proof against the disease. Important results are affirmed to have been obtained in the direction of rendering harmless the contagion of yellow fever, the scourge of tropical and semi-tropical America, by a system of inoculation with a modified virus, which renders the patient safe from the virulent form of the fever. The inoculation is said to be systematically carried on in Rio Janeiro, and with the best results.

In the field of aerial navigation, the past year witnessed some interesting experiments which appear to show that under favorable circumstances, considerable success may be had in directing the course of a balloon provided with suitable steering apparatus. The experiments here referred to were made in France by Captains Renard and Krebs.

It may be important to note that the manufacture of soda, by the ammonia process, is now to all appearances firmly established as a home industry. From information received, I am able to state that the Solvay Process Co., located at Geddes (near Syracuse) N. Y. (the pioneer, let us hope, of many to follow), have met with entire success in their enterprise. The present producing capacity of the works is 15,000 tons per annum, and the plant is about being doubled.

The continued successful operation of the Alverado Beet Sugar Company, at Alverado in California, is likewise a noteworthy circumstance. Over one million pounds of beet sugar were made at this establishment during the last season's campaign, and this in the face of direct competition with the Sandwich Island sugar imported into this country, duty free, under the Hawaiian Islands reciprocity treaty. The continued financial success of this company, convincingly demonstrates that the only questions involved in the successful domestication of this important industry, are that of proper methods and proper management.

An international conference was held at Washington during the last year, at which, the representatives of 24 nations were present to determine upon the selection of a prime meridian to be recommended for adoption by all the nations interested therein. This conference decided by an almost unanimous vote to recommend the selection of Greenwich as the universal prime meridian. It will doubtless be adopted in all the future official publications of the United States Government.

The importance attaching itself to the production of tin in the United States renders highly interesting the announcement made early in the past year, by Prof. Wm. P. Blake, that tin ore in large quantity existed in the Black Hills in Dakota. Subsequent more thorough examination has fully confirmed the fact that these deposits are both extensive and valuable. Discoveries of ores of tin have also been announced on credible authority in Rockbridge co., Va. It is probable, therefore, that this country will soon become a producer of this important metal.

SOLAR PHENOMENA IN SWITZERLAND.—In his descriptions of the colored rings by which the sun has been so often surrounded of late, Forel says that there is nothing which resembles a halo. It is a corona, which is not dependent upon the meteorological condition of the air in its lower regions. We are therefore driven to the conclusion that there is a cloud of dust suspended in the upper layers of the atmosphere. He invites the especial attention of naturalists, physicists and travelers who penetrate the upper strata of the atmosphere, whether on mountains or in balloons, to the phenomenon, and to a careful study of all the facts which they may observe.—*Comptes Rendus*, Sept. 1, 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, January* 21, 1885.]

HALL OF THE INSTITUTE, January 21, 1885.

MR. WILLIAM P. TATHAM, President, in the Chair.

Present, 164 members, and 8 visitors.

Eight persons were reported as having been elected members since the last meeting.

The Actuary reported the following resolutions adopted by the Board of Managers at their stated meeting of January 14, viz.:

Resolved, That the Standing Committee on Exhibitions, recommend to the Board the holding of an Exhibition in the fall of 1885, provided the lot of ground occupied by the Exhibition building at Thirty-second street and Lancaster avenue can be leased of the Pennsylvania Railroad Company for the purpose.

Resolved, That the Exhibition to be held shall be called the "Novelties" Exhibition.

Resolved, That the Secretary have blank forms printed for a Guarantee Fund of not less than $20,000, and that a copy of the same be sent to each member of the Institute.

Annual Report of the Board of Managers for the year 1884.

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1884:

MEMBERSHIP.

Number of new members elected		510
Lost by death or resignation	16	
Dropped for non-payment of dues	33	49
Net accessions to membership		461
The total membership at the close of the year 1884 was (approximately)		2,050

FINANCIAL STATEMENT.

Receipts.		
Balance on hand, January 1, 1884	$657 57	
Cash received from exhibition	6,909 58	
Cash received from other sources	17,941 97	
		$25,509 12
Payments.		
Cash paid interest on exhibition loans	$577 02	
Cash, all other current payments	18,002 30	
		$18,579 32
Balance on hand, December 31, 1884		$6,929 80

THE LIBRARY.

The growth of this branch of the Institute during the year 1884 has been fully maintained. Through the regular channels, the additions have been 2,547 volumes and pamphlets, to which should be added the valuable collection of special works on electricity and magnetism made for the exhibition, and which comprises 2,976 volumes and pamphlets. The total additions to the Library during the year are thus swelled to 5,547. The details will be found in the report of the Library Committee.

The old grievance of the insufficiency of room for the accommodation of the Library still exists and increases. The Board can only refer to what has been said on the subject in previous reports.

THE JOURNAL.

The business of the JOURNAL during the year 1884, though showing a slight decrease as compared with the figures of the previous year, has on the whole been satisfactorily maintained.

LECTURES.

The following lectures were, with the approval of the Board, arranged for, and delivered during the year 1884:

By Dr. Constantine Fahlberg, *three* illustrated lectures on Chemical Technology; Prof. Geo. A. Koenig, *two* (illustrated) on the Metallurgy of Silver; Prof. M. B. Snyder, *five* (illustrated) on Electricity; Mr. Theo. D. Rand, *four* (illustrated) on Mineralogy; Prof. A. J. Parker, *ten* on Animal Physics and Mechanics; Mr. Coleman Sellers, Jr., *one* on Drawing; Mr. Henry R. Towne, of Stamford, Conn., *one* on Cranes; Mr. George M. Bond, *two* on Standards of Length; Prof. Persifor Frazer, *one*, Introductory to the Chemical Course (illustrated); Mr. Richard D. Baker, *two* on Elementary Chemistry (illustrated); Wm. H. Greene, *two* on Applied Chemistry (illustrated); Dr. Bruno Terne, *two* on Agricultural Chemistry; Mr. C. John Hexamer, *two* on Fire Hazards in Textile Mills; and Prof. Persifor Frazer, *one*, Christmas Lecture to Young People (illustrated).

The above comprises thirty-eight lectures during the year. The attendance thereon was about up to the usual average of former years. The plan of issuing free tickets, admitting five minutes before the commencement of the lecture, has been continued, and appears to give general satisfaction.

DRAWING SCHOOL.

The number of pupils attending the Drawing School during the year 1884 shows a slight falling off when compared with the year

1883, which may probably be ascribed to the prevailing industrial depression. The high efficiency of the school, however, has been maintained, and improved methods of instruction and increased facilities for illustration have been introduced.

The total number of pupils in attendance during the spring term was 166, and of those at the winter term 178, making a total of 344. Some additional room has been gained for the school in the third story, by the removal of two large cases formerly devoted to the models. The Director reports that the Architectural Class is the largest we have ever had. Considering the general stagnation of all the industries, and the competition of other similar schools, which solicit and receive aid from the public, the Board feels much gratified to report that the condition of the Drawing School of the Institute is entirely satisfactory.

EXHIBITION.

During the month of September and part of October last a special exhibition of electricity, and of the means for its generation and application was held by the FRANKLIN INSTITUTE.

Notwithstanding the great expense attending the erection of buildings and machinery, the exhibition was signally successful, and it is hoped that the reports to be expected from the Examining Committees chiefly composed of gentlemen of the highest scientific reputation may be of great interest, and of value to science.

Too much praise cannot be given to the Joint Committee of the Board and Institute which managed the enterprise and brought it to a successful completion. To this and the generous liberality of the Pennsylvania Railroad Company we are indebted for the result.

The Board has had under consideration the subject of another exhibition next fall, and application to the Pennsylvania Railroad has been made for a positive lease of the ground for this year, but at this date no answer has been received.

In anticipation of a favorable answer, the Board, after mature consideration, at the meeting held on January 14, 1885, resolved to hold an exhibition to be known as a "Novelties Exhibition," and to be devoted to such recent inventions and improvements in the arts, manufactures and sciences as may be deemed worthy the name. As a preliminary step arrangements were ordered to procure a suitable guarantee fund.

SECTIONS.

The Chemical, Electrical and Phonetic Short-Hand Sections have held regular monthly meetings during the year, and the Board refers to their annual reports with pleasure, as showing a gratifying growth of their usefulness.

THE COMMITTEE ON SCIENCE AND THE ARTS.

This Committee passed upon sixteen applications during the year, in four of which they recommended the award of the John Scott legacy premium and medal. Of these recommendations two were confirmed by the Institute and approved by the Board of City Trusts, and two are still pending.

By order of the Board,

WILLIAM P. TATHAM, *President.*

PHILADELPHIA, January 14, 1885.

Report of the Committee on the Library for the year 1884.

The Committee on the Library presented the following report:

The Committee on the Library respectfully report that, during the year 1884, there has been added to the Library, on general account—

Bound volumes	1,039
Unbound volumes	480
Maps and charts	24
Pamphlets	1,028
Total	2,571

To this is to be added the "Memorial Library," which now forms part of the General Library—

Bound volumes	660	
Unbound volumes	269	
Pamphlets	1,948	
Serials	82	
Manuscripts	13	
Excerpta	4	
Total		2,976
Total addition during the year		5,547

Total number of volumes in the Library, exclusive of pamphlets, December 31, 1884, was 20,792.

A large number of valuable serial publications have been bound during the year, and a number of volumes have been rebound.

EXCHANGES.

Two hundred and sixty-seven publications, in the Library, were received in exchange for the JOURNAL during the year. Of these 136 were foreign and 140 domestic.

DUPLICATES.

The Librarian has prepared a catalogue of duplicates, which will be printed and distributed among public institutions, for the purpose of effecting exchanges.

SERIAL PUBLICATIONS.

Thirty-three serial publications have been completed during the year. Some of them, of great importance, were completed with difficulty, on account of the large gaps which were found to exist in the series.

The Committee are much indebted to one of their members—Mr. Lewis S. Ware—who, while in Europe during the past year, materially aided them in this work, as also in the advantageous purchase of many new works.

CASE ROOM.

Although new cases, of the capacity for 3,000 volumes, have been erected during the year, room is still required for about 2,000 additional volumes. The library room is now so full that but little additional space is available for the farther accommodation of book-cases.

A revised edition of the catalogue of the Memorial Library, revised and enlarged, has been prepared by the Librarian, and the revised proofs are now in the printer's hands.

Respectfully submitted,

CHAS. BULLOCK,

December 31, 1884. *Chairman of Committee on Library.*

The following report was presented by the Representative in the Pennsylvania Museum and School of Industrial Art, upon the operations of the Institution for the year 1884:

To the President and Members of the Franklin Institute:

Your Representative in the Pennsylvania Museum and School of Industrial Art offers the following report of the operations of the Museum and School for the past year:

The history of the Institution for the year is marked by only two events of interest.

First. The gift of fifty thousand dollars by Mr. J. E. Temple, in trust, the interest to be paid to him during his life, and to be used after his death for the purchase of objects for the collection and for prizes in the schools.

Second. The purchase of premises No. 1336 Spring Garden street, the removal of the School to these premises, and the extension of its departments into instruction in wood-carving, weaving, and allied branches. Beyond this, the history of the Institution has been uneventful.

Very respectfully,

WILLIAM H. WAHL, *Representative, etc.*

The Chemical and Electrical Sections also presented reports of their operations during the year.

The above reports were severally read and accepted.

Following, is a list of officers chosen at the annual election held this day:

For *President* (to serve 1 year), William P. Tatham.

For *Vice-President* (to serve 3 years), Joseph E. Mitchell.

For *Secretary* (to serve 1 year), William H. Wahl.

For *Treasurer* (to serve 1 year), Samuel Sartain.

For *Managers* (to serve 3 years), William Sellers, Hector Orr, Cyrus Chambers, Jr., Henry R. Heyl, Charles J. Shain, Charles E. Ronaldson, G. Morgan Eldridge, Hugo Bilgram.

For *Auditor* (to serve 3 years), William B. Cooper.

For *Representative in the Pennsylvania Museum and School of Industrial Art* (to serve 1 year), William H. Wahl.

COL. CHAS. H. BANES spoke as follows. "Mr. President:—I beg the indulgence of the Institute for a few moments to discharge a very pleasing duty. It is a pleasing duty, and yet brings with it some degree of onerous cares. At the early part of the preparations for the late Electrical Exhibition, it was deemed advisable to form a collection representing the literature of electricity. It was determined that proper efforts should be put forth, and proper documents sent, to authors, publishers and governments that would induce contributions to this library, which should not only be a memorial of the exhibition we have held during the last year, but should also be a valuable library for research and reference. The sub-committee to which the work was entrusted has discharged its duties very well, as you have heard from the report of the Library Committee just read by the Secretary, giving information as to the extent of its work. In extending an invitation for contributions, this sub-committee had published a document in which it agreed to do certain things. I have been requested by the sub-committee, through you, Mr. President, to make over this very valuable "Memorial Library" to the care of the Institute. I desire to ask your attention for a moment to the letter put forth by the committee, so that you may see what trust we have undertaken (reading the letter). I would say, sir, that in reply to this communication addressed to publishing houses, authors, editors, electricians and governments, there have been received thus far 3,432 volumes, bound, unbound and pamphlets. I wish to say just here, that this word "pamphlets" does not describe the full value of the communications or printed papers usually classified as pamphlets. You will find that they contain in many cases the record and evidence of original research that does not exist except in a very limited number of publications privately distributed by the inventor or discoverer among his friends and colleagues. Some of these are exceedingly interesting. One, I remember, where an investigator sent not only his papers bound, but gave the illustration of processes by which he arrived at certain results of experiments. In this collection are many volumes received from the Belgian Government; and only to-day there were received from the Italian Government over 50 volumes not included in the committee's report. Thus, you see, we may hope to receive accessions from time to time. I deliver to you, as President of the Institute, this very valuable library to be held in trust as indicated in the appeal made by the committee."

THE PRESIDENT:—"The Franklin Institute receives, with the greatest pleasure, this gift, which is the result of the enterprise and assiduous labors of the Committee on Bibliography. During the past six months I have been filled with admiration when I saw its methods of procedure, its well-directed industry and the good results that flowed therefrom, which have surprised and gratified me. I am sure the Institute owes a debt of gratitude to the gentlemen who originated the idea and carried it to completion."

The Secretary's report embraced a resumé of engineering and industrial progress during the year 1884, which appears elsewhere in the JOURNAL, and a description of several inventions. Of these the Electric Lamp of Mr. F. van Gestel is noteworthy. The invention embodies certain features which appear to be quite novel. It constitutes a species of connectin link between the arc and the incandescent lights. It consists of two copper posts or supports forming the electrodes, and through an orifice provided in the lower portion of one of them, a rod of carbon is passed, pointed at the extremity, and which is kept up in contact with the opposite pole of copper by means of a simple spring, the tension of which constantly feeds it forward, as it is consumed, and keeps it pressed up against the copper pole. In addition to this, the inventor, in order to regulate the rapidity with which the carbon burns, and to utilize all the luminous effect produced, provides a block of calcined magnesia or other highly refractory substance—lime or zirconia might be used. This block, which lasts a very long time, acts upon precisely the same principle as a sounding-board in concentrating sound impressions, in absorbing all the heat which may be given off, and becomes luminous almost as soon as electric current established. This rests on the bridge formed by the carbon rod, which insures that all the light shall be thrown downward and none wasted by being scattered in space. The light emitted is exceedingly steady.

On motion of Prof. E. J. Houston, it was resolved that the Secretary be directed to prepare and forward a petition to Congress requesting the United States Government to refund to the Institute the money expended by it for transportation and arrangement of the Government exhibits.

MR. TATHAM then spoke as follows:—"I think it hardly proper to let the present occasion pass without announcing that at the last meeting of the Board of Managers, a communication was received from JOHN VAUGHAN MERRICK (son of the second President and one of the founders of the Institute, and who himself served acceptably as its President), resigning as a member of the Board of Managers. Several years ago, he sent his resignation, with a note requesting me to make use of it whenever I thougt the interests of the Institute would be served by so doing. I never found that period to arrive, and therefore did not make use of it; but the present note was of such a nature that I could not disregard it. As he lives out of town, he could not attend the meetings of the Board, and felt as though he was not performing his duty; and, on this account, he makes his resignation positive. Should the Institute deem it proper to put any notice of the circumstance on the minutes of the meeting, an opportunity is given to do it."

On Mr. Heyl's motion, numerously seconded, the following resolution was adopted:

Resolved, That the Franklin Institute has heard with deep regret that Mr. J. VAUGHAN MERRICK finds it impossible to continue longer to serve the Institute as a Manager, and, while accepting his resignation in deference to his wishes, it does so very reluctantly, and with the full appreciation of the eminent services with which he has so long honored and aided the Institute.

Adjourned. WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIX. MARCH, 1885. No. 3.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

ON TIDAL THEORY AND TIDAL PREDICTIONS.

BY E. A. GIESELER,

Superintendent of Construction, Fourth Lighthouse District.

PREFACE.

The first part of this paper, containing a discussion of tidal theory, is to serve as an introduction to the second part, which will be given in a subsequent number of this JOURNAL, and will treat of a system of predicting tides, with especial reference to those at Cape Henlopen, Delaware Bay.

It is not intended here to render tidal theory in its completeness and all its details, nor is it intended to enter upon the various existing forms of it, excepting the one known as the Newtonian theory. With this as a basis the present theoretical discussion does not pretend to cover more than that ground only which is required for the distinct practical purpose in view.

The authorities consulted are :

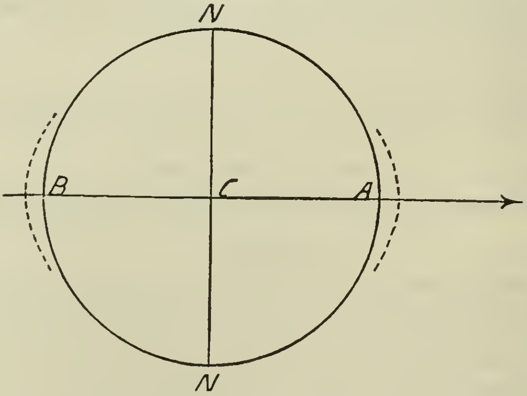
1. *Newton.* Mathematical Principles of Natural Philosophy.
2. *Whewell.* Philosophical Transactions.
3. *Lentz.* Fluth und Ebbe des Meeres.
4. *Lubbock.* An Elementary Treatise on Tides.

I. ON TIDAL THEORY.

Tides are caused by the difference in attraction exercised by Sun and Moon on those points of the Earth nearer to them, and on those points further from them.

Let us suppose the full circle in Fig. 1 to represent a section through the Earth's equator, and let us further suppose Sun and Moon both to stand in the plane of the equator and in the direction of the arrow, then the point *A* being nearest to the heavenly bodies will be attracted strongest by them, the centre, *C*, somewhat further away, will be attracted somewhat less, and the point, *B*, still further away, will be attracted still less. If the entire mass of the Earth were rigid, these various attracting forces would simply result in a movement of *C*, or the entire mass of the Earth towards the attracting heavenly bodies, and in tensile strains at all points not situated in the plane, *N N*, such tensile strains being strongest at *A* and *B*, and thence gradually diminishing to nothing at *N N*.

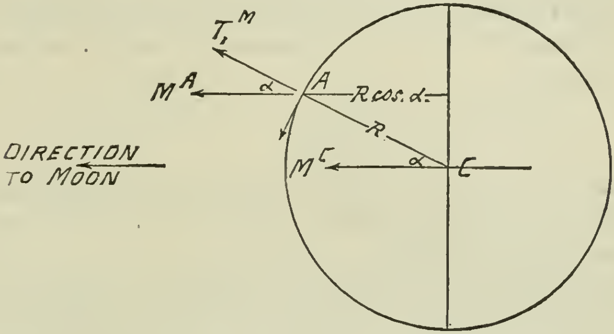
FIG. 1



If now we suppose the Earth to be surrounded uniformly by water, then there will be no molecular force to resist these tensile strains and the particles of the liquid surface between *A* and the plane *N N* are free to follow their greater tendency of motion towards the attracting bodies, that is they will move towards them in advance of the entire mass of the Earth, such motion being greatest at *A* and thence gradually diminishing to nothing at *N N*. For the same reason the particles of the liquid surface between *B* and the plane *N N* are free to follow their lesser tendency of motion towards the attracting bodies, that is they will lag behind the entire mass of the Earth, such lagging behind being greatest at *B*, and thence gradually diminishing to nothing at *N N*.

This "moving ahead" of the water on the side turned towards the heavenly bodies, and this "lagging behind" on the side turned away from them, must result in accumulations of water on both sides, the highest elevation of which must be situated at A and at B, in the direction of the heavenly bodies. The force, by the action of which these water mountains are raised is called the "tide-generating force" into the closer discussion of which we now proceed to enter.

FIG. 2.



Let us suppose the full circle in Fig. 2 to represent a section through the Earth's equator, the Moon to stand in the direction of the arrow M^c in the plane of the equator, and at the distance d from the Earth's centre, the Earth's radius to be R, and finally the directions of the attracting lunar force at the various points of our globe to be parallel amongst each other. If now the force with which the Moon acts at the Earth's centre be called M^c, and the force with which she acts at any given point, A, be called M^a, then we find according to the law of gravitation

$$\frac{M^a}{M^c} = \frac{d^2}{(d - R \cos. a)^2},$$

or,

$$M^a = M^c \frac{d^2}{(d - R \cos. a)^2}.$$

The difference

$$M^a - M^c = M^c \left\{ \frac{d^2}{(d - R \cos. a)^2} - 1 \right\},$$

shows the amount of lunar attractive force, which the particles of matter at A experience in excess of the force with which the centre or the entire mass of the Earth is attracted. Corresponding to the magnitude of such difference, therefore, the water at A will move ahead of the Earth in the direction to the Moon, and corresponding to the magnitude of the vertical component T_1^m of such difference, the water will be vertically lifted. These vertical displacements of the water are the tidal phenomena, as we observe them, and the force

$$T_1^{\mathrm{m}} = (M^{a} - M^{c}) \cos. a = \left\{ \frac{d^2}{(d - R \cos.)^2} - 1 \right\} M^{c} \cos. a,$$

is therefore the lunar tide-generating force for that side of the Earth which is turned towards her, or for the upper transit of Moon. For the other hemisphere, or for the lower transit of Moon, we find in a similar manner,

$$T_2^{\mathrm{m}} = \left\{ \frac{d^2}{d + R \cos. a)^2} - 1 \right\} M^{c} \cos. a,$$

which equation will always render a negative value, indicating that here instead of the water being lifted away from the Earth, the Earth is lifted away from the water.

Denoting the distance of the Sun from the Earth's centre by D, the force with which he acts upon the entire mass of the Earth by S^{c} and his tide-generating forces by T_1^{s} for the upper and T_2^{s} for the lower transit, we thus derive, in precisely the same way as above,

$$T_1^{s} = \left\{ \frac{D^2}{(D - R \cos. a)^2} - 1 \right\} S^{c} \cos. a$$

$$T_2^{s} = \left\{ \frac{D^2}{(D + R \cos. a)^2} - 1 \right\} S^{c} \cos. a$$

Taking the Earth's diameter as a unit, we have, for the distances of Sun and Moon, approximately

$$R = \tfrac{1}{2}, \quad d = 30{\cdot}13, \quad D = 11{,}567$$

and, introducing these values into our above equations, we now obtain for the tide-generating forces of Moon and Sun:

$$T_1^{\mathrm{m}} = \left\{ \frac{(30{\cdot}13)^2}{(30{\cdot}13 - \frac{1}{2} \cos. a)^2} - 1 \right\} M^{c} \cos. a$$

$$T_2^{\mathrm{m}} = \left\{ \frac{(30{\cdot}13)^2}{(30{\cdot}13 + \frac{1}{2} \cos. a)^2} - 1 \right\} M^{c} \cos. a$$

$$T_1^{s} = \left\{ \frac{(11{,}567)^2}{(11{,}567 - \frac{1}{2} \cos. a)^2} - 1 \right\} S^{c} \cos. a$$

$$T_2^{s} = \left\{ \frac{(11{,}567)^2}{(11{,}567 + \frac{1}{2} \cos. a)^2} - 1 \right\} S^{c} \cos. a$$

Developing the square in the denominator of the fraction, and then neglecting the very small $\frac{1}{4}$ cos.^{2} a, we have

$$T_1^{\mathrm{m}} = \left\{ \frac{30{\cdot}13}{30{\cdot}13 - \cos. a} - 1 \right\} M^{\mathrm{c}} \cos. a = \frac{\cos.^2 a}{30{\cdot}13 - \cos. a} M^{\mathrm{c}}$$

$$T_2^{\mathrm{m}} = \left\{ \frac{30{\cdot}13}{30{\cdot}13 + \cos. a} - 1 \right\} M^{\mathrm{c}} \cos. a = \frac{-\cos.^2 a}{30{\cdot}13 + \cos. a} M^{\mathrm{c}}$$

$$T_1^{\mathrm{s}} = \left\{ \frac{11{,}567}{11{,}567 - \cos. a} - 1 \right\} S^{\mathrm{c}} \cos. a = \frac{\cos.^2 a}{11{,}567 - \cos. a} S^{\mathrm{c}}$$

$$T_2^{\mathrm{s}} = \left\{ \frac{11{,}567}{11{,}567 + \cos. a} - 1 \right\} S^{\mathrm{c}} \cos. a = \frac{-\cos.^2 a}{11{,}567 + \cos. a} S^{\mathrm{c}}$$

Now, as the mass of the Moon is about 0·0125 that of the Earth, and as the mass of the Sun is about 319,500 times that of the Earth, the Newtonian law renders the following relation between the forces M^{c} and S^{c}, with which the two bodies respectively attract the Earth,

$$S^{\mathrm{c}} : M^{\mathrm{c}} = \frac{319{,}500}{(11{,}567)^2} : \frac{0{\cdot}0125}{(30{\cdot}13)^2} = \frac{173{\cdot}43}{1} \cdot$$

that is to say, the solar attractive action on our globe is somewhat more than 173 times as strong as the lunar. Taking the lunar force as a unit, we can therefore subsitute in our equations

$$M^{\mathrm{c}} = 1 \text{ and } S^{\mathrm{c}} = 173{\cdot}431$$

and by doing so we obtain

$$T_1^{\mathrm{m}} = \frac{\cos.^2 a}{30{\cdot}13 - \cos. a} \tag{1}$$

$$T_2^{\mathrm{m}} = - \frac{\cos.^2 a}{30{\cdot}13 + \cos. a} \tag{2}$$

$$T_1^{\mathrm{s}} = \frac{\cos.^2 a}{11{,}567 - \cos. a} \, 173{\cdot}431 \tag{3}$$

$$T_2^{\mathrm{s}} = - \frac{\cos.^2 a}{11{,}567 + \cos. a} \, 173{\cdot}431 \tag{4}$$

which are the final expressions for the tide-generating force of Moon and Sun, T_1^{m} and T_1^{s}, as will be remembered, being that force for the upper transit of the attracting body, and T_2^{m} and T_2^{s} being that force for the lower transit of the attracting body. Now, as the height to which the water is vertically lifted at each place stands in direct proportion to the tide-generating force acting at such place, we may also look on these equations as being expressions for the various altitudes of the lunar and solar wave above the low water plane. A scrutiny of the equations develops the fact that the value rendered by each of them is entirely dependent upon the value substituted for a, and, further, that in an absolute sense—that is apart from the algebraic sign—such value increases for a decreasing a, and *vice versa.* The angle a simply being the zenith distance at the terrestrial point in question of the attracting heavenly body, we find "that the amount of elevation caused by Moon or Sun at any given point on Earth is—apart from the variations in the distance of the heavenly bodies—entirely and solely dependent upon the zenith distance at the terrestrial point in question of the respective heavenly body, that it is the same for the same zenith distance, that it increases with a decreasing zenith distance, and that it decreases with an increasing zenith distance."

To find the relation between the lunar and the solar tidal elevations we divide equation (1) by equation (3) and equation (2) by equation (4), which will render, after a simple reduction,

$$\frac{T_1^m}{T_1^s} = \frac{11{,}567 - \cos. a}{(30{\cdot}13 - \cos. a)\, 173{\cdot}431} \tag{5}$$

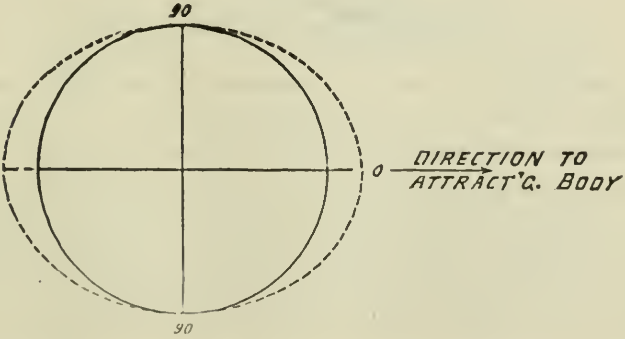
$$\frac{T_2^m}{T_2^s} = \frac{11{,}567 + \cos. a}{(30{\cdot}13 + \cos. a)\, 173{\cdot}431} \tag{6}$$

The first four of these equations enable us to compute, for different values of the angle a, the tidal elevations caused by Moon and by Sun. The figures thus obtained, without representing any actual heights, will give the proportion the various lunar and solar ordinates bear to one another. The following table renders these figures, as computed for values of a from 10 to 10 degrees, and multiplied by 100,000, in order to avoid decimal fractions. It also renders the proportion in which each lunar ordinate stands to the corresponding solar ordinate, as computed from equations (5) and (6).

	Zenith distance, *a*.	Lunar ordinate.	Solar ordinate.	Proportions between lunar and solar ordinates.
Upper transit.	0°	3,433	1,500	2·289
	10°	3,328	1,454	2·288
	20°	3,025	1,324	2·285
	30°	2,563	1,124	2·279
	40°	1,999	880	2·271
	50°	1,401	620	2·262
	60°	844	375	2·251
	70°	393	175	2·239
	80°	101	45	2·226
	90°	0	0	2·214
Lower transit.	80°	99	45	2·201
	70°	383	175	2·189
	60°	816	375	2·178
	50°	1,343	620	2·167
	40°	1,900	880	2·159
	30°	2,419	1,124	2·152
	20°	2,843	1,324	2·147
	10°	3,117	1,454	2·144
	0°	3,212	1,500	2·143

The average proportion the lunar wave bears to the solar wave, as derived from this table, is equal to the proportions they bear to each other, for $a = 90°$, viz., 2·214 : 1·000.

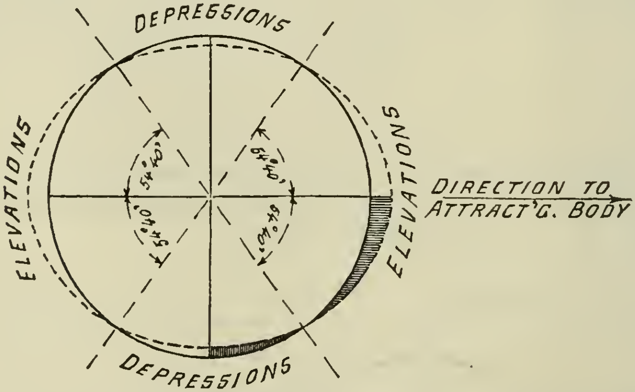
FIG. 3.



Let the full circle in Fig. 3 represent the low water circumference of the Earth at the equator, or at any other great circle, and let the dotted ellipse represent the contour of the lunar or the solar wave. This ellipse coincides with the low water line at 90°, and thence gradually rises above it until at 0° and at 180°—that is, vertically under the attracting body—it has attained its highest elevations above low water.

If now, for a moment, we imagine the attraction of the heavenly bodies not to exist, then the water mountains formed by such attractions would speedily dissolve, the mass of water contained in them distributing itself around our globe at a certain uniform height above low water, or at a certain uniform distance from the Earth's centre. This imaginary surface of water, which would exist without the action of the heavenly bodies, is called the "Surface of Mean Water," and its position (which is shown by the full circle in Fig. 4) in regard to each wave must clearly be such that the cubic contents of the tidal elevations above it are equal in amount to the cubic contents of tidal depressions below it.

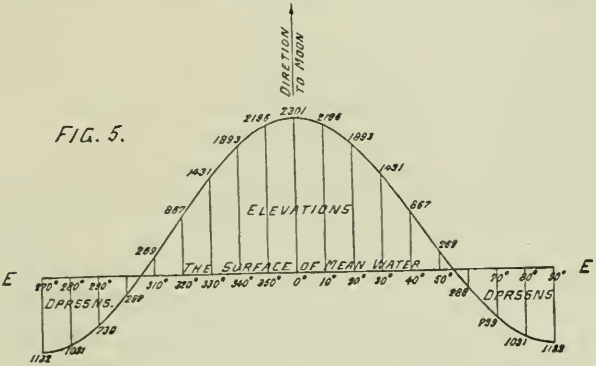
FIG. 4.



In other words, that the cubic contents of the two solids formed by an entire revolution of the two shaded areas in Fig. 4, around the line of direction to the attracting body as an axis, are equal. This is the case for a value of a of about 54°40′; at this point, therefore, the surface of mean water intersects the tidal waves; in other words, at this point the surface of mean water undergoes no change through the action of the heavenly bodies; for values of a greater than 54°40′ it is depressed, for values of a smaller than 54°40′ it is elevated.

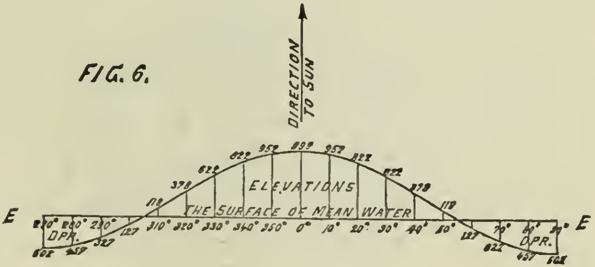
The diagrams, figs. 5 and 6 show the lunar and the solar wave in their proper positions relative to the mean water surface. Both heavenly bodies are supposed to stand in the plane of the equator and in the meridian 0°; the semi equator in both cases is developed into the straight line EE for the sake of clearer representation and the figures of elevation and depression are entered as derived from our table with reference to the surface of mean water. The corresponding figures for the waves incident on lower transits will of course be slightly different.

FIG. 5.



THE LUNAR WAVE

FIG. 6.

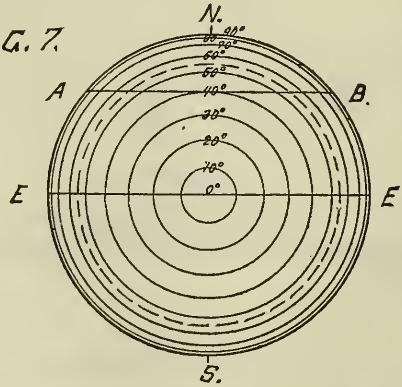


THE SOLAR WAVE

Fig. 7 represents the *lunar,* and *respectively the solar,* wave in its horizontal projection, each of them covering one-half of our globe. The *Moon,* and *respectively the Sun,* is supposed to stand vertically above the centre, the concentric circles around which are marked 10°, 20°, etc., according to their zenith distance from the attracting body; the dotted circle at 54°40′ is the neutral circle on the circumference of which there is neither elevation above nor depression below the plane of mean water.

The point marked 0° is the point of highest elevation; the outer circle marked 90° is the circle of lowest depression or the circle of low water. Inside the neutral circle or the circle of mean water, the water is elevated, outside of it it is depressed, and these elevations above and depressions below the surface of mean water are the same along the circumference of one and the same circle, corresponding in each case to the figures of diagrams *5*, and, *respectively*, *6*. These diagrams and their figures refer, as stated above, to the component waves on the equator only. The conditions on the various latitudes north and south of the equator will be different, and in order to develop them for any given latitude, we simply examine where the various concentric tidal circles intersect such latitude and according to the position of such points of intersection we easily obtain the diagrams of its component waves. On Fig. 7 latitude 40° north has been entered, and we perceive at a glance that the highest point of each wave on it is contributed by circle 40°, corresponding to a highest solar elevation of 378, and a highest lunar elevation of 867, while the intersection of mean water surface and tidal wave on latitude 40° is at a distance of only about 41° longitude from such highest point.

FIG. 7.



The solar and the lunar wave, the generating of which we have discussed above, are constantly moving over the oceans independently of each other. The formation of one does in no way interfere with or modify that of the other, and the resulting tidal wave is created simply by a process of summation of the two component waves, a process that we can best picture to ourselves by imagining one of the component waves laid on the top of the other. The most simple case of this process of summation takes place when Sun and Moon stand in the same direction; then the corresponding parts of the two waves will add themselves to each other; for instance the highest lunar elevation will rest on the highest solar elevation and the lowest lunar depression will stand under the lowest solar depression (Fig. 8). If Sun and Moon were always to stand in the same meridian, with an equal and constant declination, say, for instance, both always moving in the plane of the equator, then this would always be the way in which the two waves sum themselves. Both the Sun's and the Moon's tide-generating forces would then be united in the same direction, thus raising a resulting tidal wave the height of which would be equal to the sum of both component waves, being greatest at the equator, thence gradually diminishing towards north and south and finally running out into nothing at the poles. The circle of low water passing through the polar axis and hence always standing perpendicular on the plane of the equator as well as the planes of all other latitudes, would on every one of them divide the spaces between the two high waters into two equal parts each, that is, the duration of rise would everywhere be equal to the duration of fall, and thus each point on our globe under these circumstances would have two equally high high waters and two equally high low waters daily, the space of time intervening between them being six hours everywhere.

In reality, however, the heavenly conditions causing tides instead of being as simple and uniform as supposed above, are subject to constant changes, the principal ones of which may be designated as follows:

1. The changes in the distance of Sun and Moon from our globe;
2. The changes in the relative meridional position of Sun and Moon;
3. The changes in the declination of Sun and Moon.

We now proceed to discuss each of these as far as our subject requires it.

1. THE CHANGES IN THE DISTANCE OF SUN AND MOON FROM OUR GLOBE.

The Moon's orbit is an ellipse, one focus of which is occupied by the Earth, and during her revolution in this orbit the Moon therefore constantly changes her distance from our globe. The time occupied by one complete revolution of 360° around the Earth being measured by the Moon's return to the same fixed star, such revolution is called "sidereal revolution," from the Latin "sidus," star. The sidereal revolution occupies about 27¼ days, and during this time we observe the Moon conforming to the above pass from her greatest distance to her smallest distance and back again to her greatest distance. Owing to the perturbing influence of the Sun, the extreme limits of the Moon's distance from us, that is to say, the semi great axis and the semi small axis of her orbit are not constant, but vary in a period of about nine years.

The earth's orbit is likewise an ellipse, one focus of which is occupied by the Sun, and during her revolution in this orbit the Earth therefore constantly changes her distance from the Sun, passing in the space of one year from her greatest distance (in summer) to her smallest distance (in winter) and back again to her greatest distance.

2. THE CHANGES IN THE RELATIVE MERIDIONAL POSITION OF SUN AND MOON.

If to-day Sun and Moon have culminated simultaneously, then to-morrow her own motion has carried the Moon about 12° east of the Sun and she will consequently culminate about 49 minutes after him; a day later she will stand about 24° east of the Sun, culminating about 1 hour 38 minutes later, and so on until after about 14¾ days she culminates 12 hours later than the Sun and finally after about 29½ days both heavenly bodies once more culminate simultaneously. This period of 29½ days elapsing between two conjunctions of Sun and Moon, inside of which we observe the Moon successively culminating in each of the 24 hours of the day, is called the "synodical month:" it would be equal in duration to the siderial revolution if the Earth merely rotated around its axis, without at the same time traveling around the Sun; but through the Earth's revolving around the Sun the position of the latter on the ecliptic is constantly shifting to the eastward and the Moon having after 27¼ days completed one sidereal revolution finds the Sun in a position so much more easterly that she has to travel about 2¼ days more before reaching his meridian, or as it was expressed above, before getting in conjunction with the Sun.

3. THE CHANGES IN THE DECLINATION OF THE SUN AND MOON.

The plane of the Earth's equator forms an angle of about 23½° with the plane of her orbit (ecliptic). Hence the varying declination of the Sun which is zero when our globe is at either point of intersection between the equator and the ecliptic (vernal and autumnal equinox) and which thence gradually rises to about 23½° north or south when our globe is 90° from those points at the solstitials.

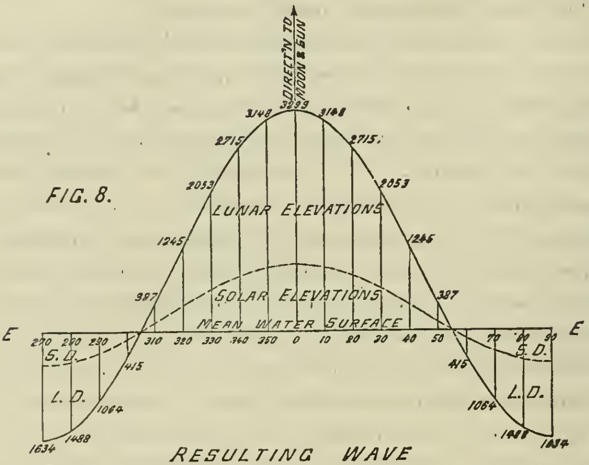
If the Moon's orbit were in the plane of the ecliptic, then it is clear that the limits of the lunar declination would be the same as those of the solar declination, viz., about 23½° north and south. In the period of one sidereal revolution the Moon would pass from 23½° declination on one side of the equator to 23½° declination on the other side, and thence return again to the original declination. The Moon's orbit, however, does not lie in the plane of the ecliptic, but is inclined to it somewhat more than 5° and according to the position of the lunar nodes (which is not fixed but revolving around the Earth) this inclination or part of it will either add to or subtract itself from the above angle to form the highest lunar declination for the time being. Such maximum lunar declination therefore ranges between about 18° and about 29°, and all the various stages of it are contained in a period of about 19 years, inside of which the nodes of the Moon's orbit complete their circle around the earth. At the time this is being written (beginning of October, 1884,) the maximum declination of the moon has its lowest possible value, somewhat more than 18°; it will now commence to increase and in about 9½ years will attain its highest limit, about 29°. At present, therefore (October, 1884), the Moon passes in the period of one sidereal month from a maximum declination of about 18° on one side of the equator, across the latter to about the same maximum declination on the other side and back again to the original declination.

Having in the above discussed the peculiarities of the motion of the heavenly bodies as far as required for the final purpose in view, we now proceed to investigate their influence on tides.

THE INFLUENCE EXERCISED ON TIDES BY THE CHANGES IN THE RELATIVE MERIDIONAL POSITION OF SUN AND MOON, OR THE SEMI-MENSTRUAL INEQUALITY OF TIDES.

In order to find how tides are influenced by the above-described changes in the relative meridional position of the heavenly bodies we will start from the simultaneous culmination of both and the tidal wave created by it. Let the straight line in Fig. 8 represent the developed semi-equator on the surface of mean water and let the dotted line be the solar wave, Sun and Moon standing in Meridian 0°, in the plane of the equator.

FIG. 8.



RESULTING WAVE

Now, by erecting our lunar elevations and depressions at the corresponding points of the solar wave, we obtain the resulting tidal wave (shown in a full line) described above, that is, the one having the highest range, which is called "Spring tide." It is evident that in this case the high water must be vertically under the two attracting bodies, because there the two highest elevations combine and it is also evident that in this case the low water must be 90° distant from the attracting bodies, because there the two lowest depressions combine. High water, therefore, in this case takes place simultaneously with the culmination of the heavenly bodies and low water takes place 6 hours 24½ minutes after it.

FIG. 9.

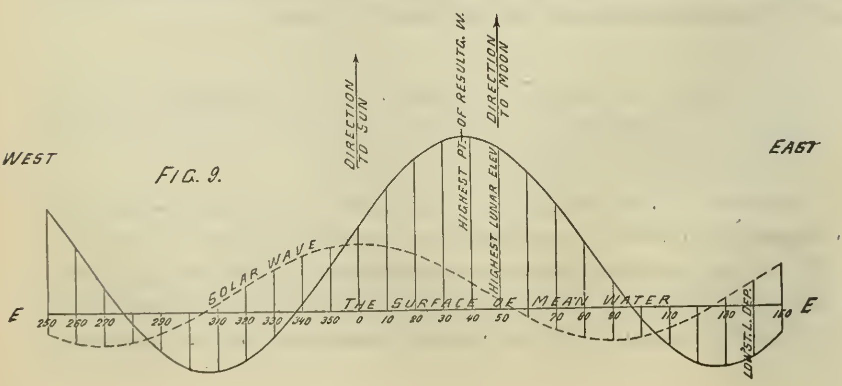
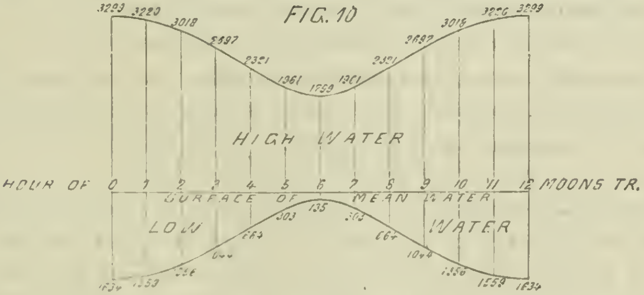


Fig. 9 represents the situation as it will be four days after the above, when the Moon culminates about 3 hours later than the Sun.

It is clear at once that the high water now must be lower and the low water must be higher than in the last case, because the extreme elevations and depressions of one wave now combine with the lesser elevations and depressions of the other wave. Thus the high water will continue to become lower and the low water will continue to become higher, with the growing lateness of the hour of the Moon's transit, the highest lunar elevations successively combining with lower and lower points of the solar wave, and the lowest lunar depressions successively combining with higher and higher points of the solar wave. Finally, about 7½ days after the simultaneous culmination of the heavenly bodies, when the Moon culminates 6 hours later than the Sun, the highest lunar ordinate will combine with the lowest solar depression, there creating the lowest possible high water, and the lowest lunar depression will combine with the highest solar elevation, there creating the highest possible low water, which extreme case is called "Neap tide." Thenceforward the high water will again become higher and the low water lower, both once more reaching their maximum, the "Spring tide," after about 14¾ days, when Sun and Moon stand in opposition, that is, when the Moon culminates 12 hours after the Sun; then, as in the case represented in Fig. 8, the extreme elevations and depressions caused by one, once more combine with those caused by the other.

FIG. 10



THEORETICAL CURVES OF SEMIMENSTRUAL INEQUALITY OF HEIGHT

The half-monthly series of changes in the height of tides, above described, is represented in the diagram (Fig. 10), the figures of which refer to tides incident on upper transits.

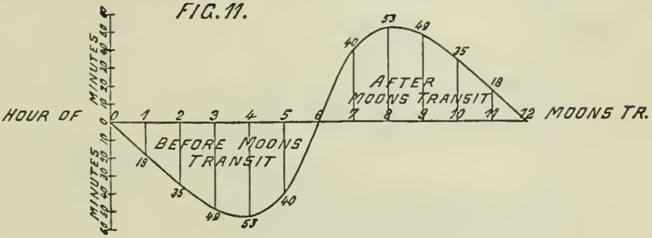
The straight line is the surface of mean water, and on it are laid off the hours of Moon's culmination. Vertically to it, above and respectively below, are laid off the theoretical heights of high water, and, respectively, low water pertaining to each hour of culmination; the curves joining the points so obtained are called the curves of the semi-menstrual inequality of the height of high and low water.

Besides the *height*, the *time* of high and low water is also influenced by the varying meridional position of the Moon relative to the Sun. Let the conditions be exactly the same as those represented in Fig. 9, then the greater lunar elevation not standing any more on the highest point of the solar wave, but on a much lower one, is not able there to produce the highest point of the resulting wave. This will be created by a lunar ordinate, not much lower than the highest one, which, however, rests on a much higher point of the solar wave. The position of high water will thus be shifted from, vertically, under the moon to somewhat to the westward of it; that is, high water instead of taking place simultaneously with Moon's transit, will take place before it. The same deduction applies to low water. The lowest lunar depression combining with a comparatively high point of the solar wave is not able there to form the lowest point of the resulting tidal wave, but this will be formed by a lunar depression not much smaller than the lowest, which combines with a much lower point of the solar wave. The position of low water will thus also be shifted westerly, and the time interval elapsing between Moon's transit and low water, instead of being 6 hours 24½ minutes, will now be less than that.

Starting from the time of simultaneous culmination of Sun and Moon (Spring tide), the above described precession of the time of high and low water will increase, day by day, with the growing lateness of the Moon's culmination until after about 5 days, when the Moon culminates about 4 hours later than the Sun, the maximum is reached; thenceforward the precession will decline until after about 7½ days, at Neap tide, when the Moon culminates 6 hours later than the Sun, the precession becomes zero, that is, high water and Moon's transit are once more simultaneous. Thenceforward high and low water will be retarded, such retardation reaching its maximum after about 10 days, when the Moon culminates about 8 hours later than the Sun; thenceforward it will decline until after about 14¾ days, at Spring tide, when Sun and Moon stand in opposition, it becomes zero, that is, high water and Moon's transit are again simultaneous.

Fig. 11. will serve to illustrate this series of half-monthly changes in the time of high and low water, as referred to the time of Moon's transit.

FIG. 11.



THEORETICAL CURVE OF SEMIMENSTRUAL INEQUALITY OF TIME

Vertically to the abscissa, which represents the time of Moon's transit, are laid off the precessions and retardations theoretically pertaining to each hour of Moon's transit; the curve joining the points so obtained, is called the curve of the theoretical semi-menstrual inequality of the time of high and low water.

This inequality in the time of tides is, however, modified by the fact that the simultaneous occurrence of high water and Moon's transit, which for the Spring tide is assumed by theory, never and nowhere happens in reality. The tides in all cases occur later than the lunar transit that caused them, and the time elapsing between the two is called the "lunitidal interval." The above-found inequality in time will, therefore, in practice become apparent by the lengthening and shortening of the lunitidal interval for high water as well as for low water.

THE INFLUENCE EXERCISED BY THE DECLINATION OF THE MOON, OR THE DIURNAL INEQUALITY OF TIDE.

It is clear that the above-discussed variations in the Moon's declination must cause corresponding changes in her zenith distance from any given point, and thus influence the height of tide which, as we have seen, is dependent on the zenith distance of the attracting body.

To further illustrate this, let *A*, Figs. 12 and 13, represent a point somewhere on latitude 30° north, where an observer is stationed, the full drawn circle in both cases being a section through the Polar axis. Fig. 12 represents the situation when he observes a tide incident on the upper lunar transit, while Fig. 13 represents the situation about $12\frac{1}{2}$ hours later, when through the Earth's rotation the point A has passed to the other side (the Moon in the mean time, not having materially changed her position), and a tide incident on the lower transit is observed. Now, if the Moon's declination is 10° north, then in the case of the upper transit her zenith distance, or the distance of the apex of the lunar wave from the observer is 30°—10°=20° while in the case of the lower transit it is 30°+10°=40°; in the first case, the height of tide h must, therefore, be a higher one than in the second case, as shown in the diagrams. We consequently see that on our (northern) hemisphere during northern declinations of the Moon, a higher lunar contribution towards the tide is rendered by upper transits than by lower transits of the Moon, and it is equally clear that precisely the reverse must be the case during southern declinations of the

FIG. 12.

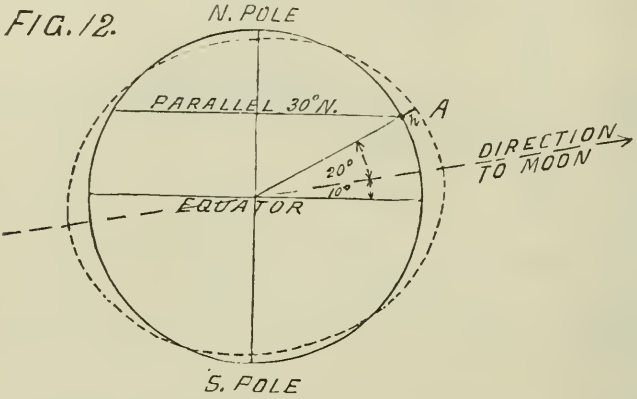
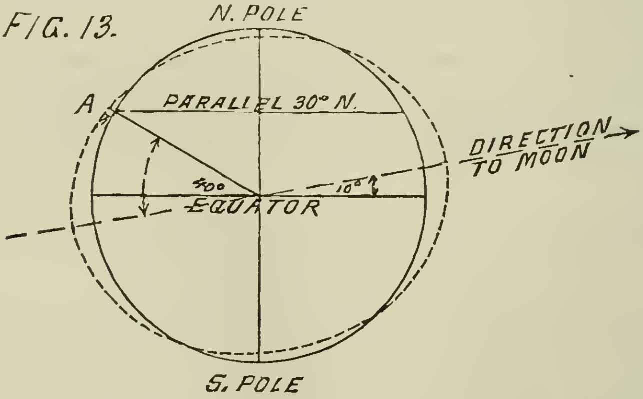


FIG. 13.



Moon; that is, that then the lower transits will render a higher contribution than the upper ones. We may, therefore, with reference to lunar declination, divide all high waters into two groups as follows:

1st Group.—High waters incident on:

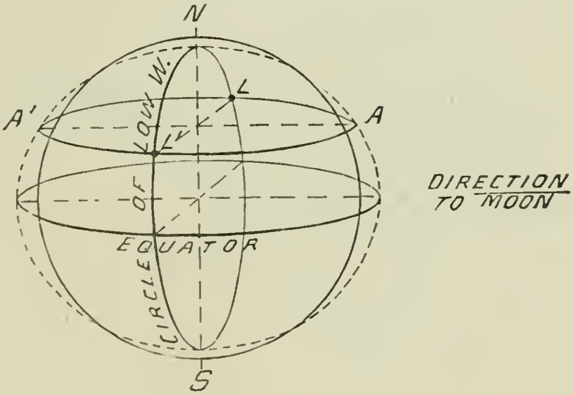
Upper transit of Moon during Southern declination;
Lower transit of Moon during Northern declination;
which are the *lower* high waters, and

2d Group.—High waters incident on:

Upper transit of Moon during Northern declination;
Lower transit of Moon during Southern declination;
which are the *higher* high waters.

Two tides (or high waters) following each other cannot, ordinarily, belong to the same group; the above established law will, therefore, find its expression in the difference in height, between the two high waters of the same day, and hence such difference is termed the diurnal or daily inequality in the height of tide.

FIG. 14.

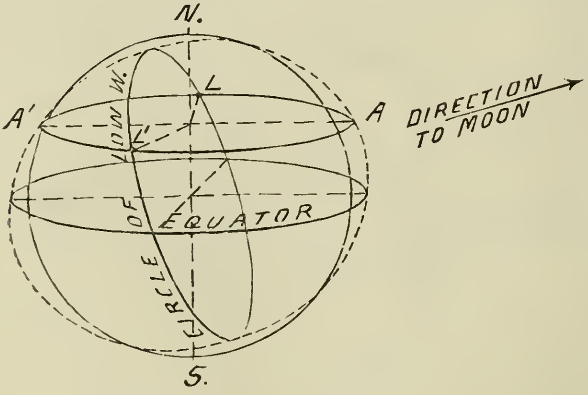


A simple reflection will show that, in the tides of the first group, the *greater* declination always produces the *lower* tide, while in the tides of the second group, the *greater* declination always produces the *higher* tide. The diurnal inequality consequently increases and decreases with the increase and decrease of the Moon's declination, and it would be reduced to zero, if the Moon was to stand in the Equator, during two high waters following each other. This, of course, can never be; yet, when the Moon is in the immediate vicinity of the Equator, it generally happens that two tides following each other belong to the same group, because the Moon, during the time that she passes from her upper to her lower transit, or *vice versa*, also passes the Equator, thereby changing her declination from North to South, or *vice versa.* In these cases therefore the small diurnal inequality that is at all possible, when the Moon stands near the Equator, may be annulled entirely.

Another important influence is exercised by the Moon's declinations on the duration of rise and fall.

When the Moon stands in the Equator, Fig. 14, then the circle of low water passes through the polar axis, dividing the two equal spaces from A to A', and from A' to A, into two equal spaces each. The time it takes the observer to pass from the high water at A, to the low water L, thence to the high water A', thence to the low water L', and thence to the high water A, is therefore the same in all cases, that is to say, rise as well as fall consume the same amount of time each, viz., about 6 hours $24\frac{1}{2}$ minutes in all cases.

FIG. 15.



But when, as in Fig. 14, the Moon declines northerly, then the circle of low water is tilted into a slanting position to the polar axis, and the duration of the fall A L, and the rise L' A becomes longer, while the duration of the rise L A', and of the fall A' L' becomes shorter. It will be noticed that the difference is due only to a shifting in the point or time of low water, the two high waters retaining their former position and distance from each other. Referring the time of low water to that Moon's transit which has caused the preceding high water, we can, therefore, exhaustively express this difference by saying that through the

Moon's declination the low water at L is *belated*, while through the same agency the low water at L' is made to come *earlier*. Or, calling the space of time between the low water and the lunar transit which caused the preceding high water, "the low water lunitidal interval," we may say, generally, that when the Moon declines northerly the lunitidal interval of the low water incident on the upper transit will be lengthened, and the lunitidal interval of the low water incident on the lower transit will be shortened through the Moon's declination. It will be understood, without further explanation, that the exact reverse takes place for southern declinations of the Moon.

This difference in the length of lunitidal intervals of every two low waters following each other, is called the diurnal inequality of the time of low water, and, according to the above, we can classify in reference to it in a similar way, as has been done before, in reference to the inequality of height, viz.:

1st Group.—Lunitidal intervals of low waters incident on:

Upper transits of Moon during Southern declination;
Lower transits of moon during Northern declination;
which are the *shorter* low water lunitidal intervals, and

2d Group.—Lunitidal intervals of low waters incident on:

Upper transits of Moon during Northern declination;
Lower transit of Moon during Southern declination;
which are the *longer* low water lunitidal intervals.

We perceive that in the first group the *greater* declinations must always produce the *shorter* lunitidal intervals, while in the second group the greater declination must always produce the *longer* lunitidal intervals. Consequently the diurnal inequality of the time of low water, like the diurnal inequality of the height of high water, increases and decreases with the increase and decrease of the Moon's declinations, and when the Moon is in the immediate vicinity of the equator vanishes entirely.

The declination of the heavenly bodies also causes a diurnal inequality in the time of high water. If, for instance, the Moon declines northerly and the Sun southerly, the Moon culminating, say, in the second hour, then during her upper transit the 2d group (higher) lunar wave combines with the 1st group (lower) solar wave, while twelve hours later, during the Moon's lower transit, the 1st group (lower) lunar wave combines with the 2d group (higher) solar wave; it is clear that a difference in the time of the two high waters following each other must be the result of this.

It should be understood that the above discussion of the diurnal inequality treats of the *Northern* hemisphere only; for the *Southern* hemisphere group No. 1 would take the place of group No. 2, and *vice versa.* At the equator no diurnal inequality, neither of the height of high water nor the time of low water, exists.

THE INFLUENCE EXERCISED ON TIDES BY THE CHANGES IN DISTANCE OF SUN AND MOON FROM OUR GLOBE.

It is, *a priori*, evident that the changes in distance of the heavenly bodies must cause corresponding changes in the height of the component waves raised by them. The nearer either heavenly body is to us the higher will be the component wave raised by it and *vice versa.* At the same time the proportion between the two waves, which in the mean we have found to be as 2·214 : 1, is likely to be affected, and in order to find to which degree this may be the case, we will divide the general expression found for T_1^m by the one found for T_1^s (page 000), this division renders:

$$\frac{T_1^m}{T_1^s} = \frac{d^2 - (d - R\cos.\,a)^2}{(d - R\cos.\,a)^2} \cdot \frac{(D - R\cos.\,a)^2}{D^2 - (D - R\cos.\,a)^2}\,\frac{M^c}{S^c}$$

$$= \frac{(2d\,R - R^2\cos.\,a)\,(D - R\cos.\,a)^2}{(d - R\cos.\,a)^2\,(2D\,R - R^2\cos.\,a)}\,\frac{M^c}{S^c}$$

In this equation a may have had value between 0° and 90°; by putting $a = 90°$ we will at once simplify the calculation and obtain a result, which is a mean between the upper and the lower transit waves. For $a = 90°$ we obtain

$$\frac{T^m}{T^s} = \frac{2d\,D^2\,R}{2D\,d^2\,R}\,\frac{M^c}{S^c} = \frac{D}{d}\,\frac{M^c}{S^c}$$

Introducing now the value of the proportion $\frac{M^c}{S^c}$ as obtained before according to the Newtonian law, we have

$$\frac{T^m}{T^s} = \frac{D}{d}\,\frac{\dfrac{0{\cdot}0125}{d^2}}{\dfrac{319500}{D^2}} = \frac{D^3\,0{\cdot}0125}{d^3\,319500}$$

We perceive, therefore, that the proportion of the lunar to the solar wave, varies indirectly as the third power of the distance of the heavenly bodies varies. Now the difference between the greatest and least distance on the one side and the mean distance on the other side for the Sun amounts to about $\frac{1}{60}$ of the latter and for the Moon to about $\frac{1}{17}$. Supposing now the Moon to be in her greatest vicinity to the Earth, and the Sun to be at his greatest distance, then the above equations will render this result:

$$\frac{T^m}{T^s} = \frac{\left\{11567 + \frac{11567}{60}\right\}^3}{\left\{30{\cdot}13 - \frac{30{\cdot}13}{17}\right\}^3} \; \frac{0{\cdot}0125}{319500} = 2{\cdot}783$$

And again supposing the Moon to be at her greatest distance from the Earth, while the Sun is in his greatest vicinity, then the above equations will render this result:

$$\frac{T^m}{T^s} = \frac{\left\{11567 - \frac{11567}{60}\right\}^3}{\left\{30{\cdot}13 + \frac{30{\cdot}13}{17}\right\}^3} \; \frac{0{\cdot}0125}{319500} = 1{\cdot}773$$

We therefore perceive that the proportions of the lunar wave to the solar wave, which for the mean distance of both bodies we had found already to be 2·214, is a quantity varying between the two extreme limits of 2·783 and 1·773.

For the mean distance of both heavenly bodies the proportion between spring and neap tide can be expressed thus:

$$\frac{\text{Spring tide}}{\text{Neap tide}} = \frac{2{\cdot}214 + 1{\cdot}000}{2{\cdot}214 - 1{\cdot}000} = \frac{3{\cdot}214}{1{\cdot}214} = 2{\cdot}648$$

The two extreme cases, however, will be

$$\frac{\text{Spring tide}}{\text{Neap tide}} = \frac{2{\cdot}783 + 1{\cdot}000}{2{\cdot}783 - 1{\cdot}000} = \frac{3{\cdot}783}{1{\cdot}783} = 2{\cdot}122 \left\{ \begin{array}{l} \text{Moon at least and} \\ \text{Sun at greatest} \\ \text{distance.} \end{array} \right.$$

$$\frac{\text{Spring tide}}{\text{Neap tide}} = \frac{1{\cdot}773 + 1{\cdot}000}{1{\cdot}773 - 1{\cdot}000} = \frac{2{\cdot}773}{0{\cdot}773} = 3{\cdot}587 \left\{ \begin{array}{l} \text{Moon at greatest} \\ \text{and Sun at} \\ \text{least distance.} \end{array} \right.$$

Besides the above-mentioned influences, the variations in the distance of the heavenly bodies also exercise an influence on the time of high and low water, because the lunitidal intervals of high and low water must be the shorter the nearer the heavenly bodies are to us, as the higher wave raised by them then, will move swifter than a lower one, raised when they are further off.

The semi-menstrual inequality, the diurnal inequality and the inequalities caused by the variations in the distance of Sun and Moon, each of them represent a series of regular changes occurring within a short period of time, the duration of which is a different one in each case and the various phases of which are, therefore, constantly shifting their position towards each other. Besides this, the limits of lunar parallax and declination are not constant, but, as we have seen vary, in periods of 9½ to 19 years respectively; this latter period of time then would be the one at the expiration of which the heavenly tide-generating conditions would repeat themselves in the same combinations, if it were not for additional complications being introduced through variations in the limits of solar declination and distance. These being of no practical importance, however, will not be discussed here, beyond stating, that strictly speaking, many thousand years must elapse before the heavenly tide-generating conditions can repeat themselves in precisely the same combinations.

The sidereal causes affecting tides, can as we have seen, be brought into a theoretical system based upon exact science. If there were no other interfering influences, and if all the suppositions on which we have founded our theory were correct, then tides would occur conforming to the same, and the time and height of any high or low water, at any given place on Earth, could be predicted with absolute certainty.

But, in the first place, our suppositions are not correct. We have assumed the Earth to be surrounded uniformly by water, which as we know is not the case. The oceans are bounded everywhere by continents, and even the largest of them, the Pacific Ocean does nowhere extend over more than 90 degrees of longitude, while the tidal wave of theory extends over 180 degrees. Consequently, even our largest ocean is far from offering the conditions of size required for the formation of a tidal wave, according to theory.

Again, we have assumed "that in the water there are no molecular forces resisting the actions of the tide-generating forces," that is that the particles of water are devoid of cohesion. This assumption, although approximately correct, is known not to be strictly so and is made only in default of accurate knowledge on the subject. As long as an intimate knowledge of this property of water and of the laws governing the motion of its particles is not obtained our theoretical results regarding the raising and propagating of tidal waves necessarily are only approximately correct.

Nor is this all; a number of other terrestrial causes combine to continually influence and modify the generation of the tidal waves. In deep water the wave will move swifter and rise higher than in shallow water. In long and narrow bays we frequently find astonishing heights of tide, while at a projecting point of the coast line, perhaps close by the rise is insignificant. The influence exercised by the topographical formation of coast lines is strikingly described by Lentz, ("*Ebbe und Fluth des Meeres*," Hamburg, 1873), in the following words:

"The intricate theoretical tide-generating conditions are complicated still more by a number of other circumstances, thus forming a bewildering labyrinth of causes and results, through which the human mind cannot find its way. The tidal waves meeting islands in their course are parted by them, and a wave reaching a certain point by one road will there meet another one that has arrived at the same point by another road. Both will penetrate each other, will locally annul and locally augment each other, according to the way they meet and a wave thus combined will take a new course with an altered height and velocity until it meets a third wave with which it will form new combinations, and thus an endless series of varying phenomena, impenetrable to the human eye, will be created.

"The numberless tidal waves rushing through the oceans in all directions, we cannot better picture to ourselves than by throwing ten or twenty stones into a small pond and then watching the various systems of waves that in the course of a few moments have formed on the surface and are now traveling in all directions, crossing, penetrating, annulling and augmenting each other. If we were to observe at a few given points on the banks of this pond the forms of waves appearing there, then from such local observations we would learn about as much of the various systems moving on the surface of the pond, as we now know about the tidal waves moving on our oceans."

Lentz adds: "This certainly is discouraging, we only know that we do not know anything," and so far as our knowledge of the phenomena in open ocean is concerned he certainly is right. We can only gain an insight into the phenomena as they appear on our shores, where actual observations can be made, and although the results of these will nowhere be found to exactly correspond to theory and will even frequently depart very far from it, yet the laws of the latter can always be recognized in long series of local observations, modified in each case by those local constants that are produced through terrestrial influences at the particular point of observations.

Besides the local causes influencing tides, which emanate from the topographical and hydrographical features of the locality and its surroundings, and which, therefore, are of a permanent character, there are a number of other terrestrial influences of a varying and fluctuating description, such as wind, temperature, barometrical pressure, atmospherical precipitations, etc. Although in the means of a sufficiently long series of observations these influences will have a constant value, yet to the individual case they impart a vacillating character, which cannot be framed into any law, and thus they form the source of unavoidable discrepancy between prediction and actual observation.

Assuming, as above, that a period of nineteen years contains practically all the possible combinations of the heavenly tide-generating conditions, then the means of all the tides at a certain place during such period may be looked upon as the *mean tidal establishment* of the locality, the principal items of which are as follows:

MEAN TIDAL ESTABLISHMENT.

1. The corrected establishment, or high water mean lunitidal interval.
2. The low water mean lunitidal interval.
3. The mean height of high water.
4. The mean height of low water.

From these, by means of simple operations, the duration as well as the range of tides can be found.

These mean values, as deduced from a series of nineteen years, correspond to certain mean values of the heavenly tide-generating conditions, and, in order to test to what extent the means of a shorter period (supposing a full one is not available), deviate from the values of the true mean establishment, we have to compare the means of the heavenly conditions in the latter case with those of the first case. If they are equal in both cases, then we are justified in presuming that our shorter series has rendered the values of the true mean establishment. If they are not equal then corrections must be applied as will be shown subsequently.

The mean establishment once found, then in order to compute or predict the *time* of high or low water for any individual case, we simply add to the mean lunitidal interval of high water and respectively low water, the corrections for the hour of moon's transit, for declination and for parallax of the heavenly bodies.

In order to find the *height* of high or low water we have to construct from the known resultant wave the two component waves. Having done this the height for high as well as low water, for any given individual case, is determined by the equation.

$$\text{Height} = M^{\alpha} + S^{\beta}$$

wherein

α = Zenith distance of Moon from the place of high and respectively low water, at the time of the generating lunar transit.

M^{α} = Lunar elevation or depression pertaining to such zenith distance.

β = Zenith distance of Sun from the place of high and respectively low water, at the time of the generating lunar transit.

S^{β} = Solar elevation or depression pertaining to such zenith distance.

The values M^{α} and S^{β} will be influenced by the varying distances of the heavenly bodies and have to be corrected according to the determined magnitude of such influence.

The deduction, from actual observations made at a certain point, of the local laws governing tides there, and of a system for predicting them, resolves itself as we see into:

1. The determination of the local mean tidal establishment.
2. The determination of the influence of lunar and solar declination and parallax on time and height of high and low water.
3. The resolution of the resultant tidal wave into its two component waves.

The way in which the first problem is approached has been indicated already.

The general method of solving the second problem will be to group the available observations in such a way, that two groups will render means in which the sidereal conditions are alike with the exception of one of them. Then the inference is justified, that the differences found in the means of the observations (be it time or be it height) are due to the difference in that only one of the sidereal conditions, the mean of which is unequal in the two groups, and this inference will be all the safer, the greater the number of observations is which compose each group.

The third problem is solved in the same way, the unequal means of sidereal conditions here always being the zenith distance of either Sun or Moon. The resulting differences of height then must be the differences of height between the various concentric circles of either the lunar or the solar wave (Fig. 7) and by means of a sufficient number of such differences the contours of the component waves can easily be determined.

The introduction of the zenith distance, in the equations for height, is advantageous, in so far as in the place of two unknown quantities—the influence of declinations and of hour of Moon's transit—we only have to deal with one—the influence of the zenith distance. It necessitates the construction of tables from which the zenith distance of Moon and Sun from the place, respectively, of high and low water, at the time of the generating lunar transit, can be found, pertaining to each hour of Moon's transit and each degree of declination on either side of the Equator. These tables as constructed for Cape Henlopen, Delaware Bay, will be given in the second part of this paper; they are applicable for any place in the vicinity of latitude 40° N, the corrected establishment of which does not materially deviate from that of Cape Henlopen.

INFRA-RED EMISSION SPECTRA.—By the use of a new form of spectroscope and of a suitable phosphorescent material, which has been previously rendered luminous, Henri Becquerel has been able to subject the lines and active bands in the lower portions of emission spectra to microscopic examination and to determine the wave lengths of the most brilliant lines in some of the incandescent metallic vapors, such as potassium, sodium and cadmium, by projecting the diffracting spectra furnished by one of Rutherford's very beautiful metallic rulings. The results show a remarkable richness in the infra-red region, which comprises an interval of wavelengths more extensive than the aggregate of the visible region and of the ultra-violet region. The investigation seems likely to furnish valuable information concerning still unknown laws which regulate the vibratory movements of incandescent vapors.—*Comptes Rendus*, Aug. 25, 1884. C.

STAR PHOTOGRAPHY.—The application of photography to the construction of star charts, which was introduced many years ago by Rutherford & Gould, has lately been undertaken at the Paris Observatory, by the Messieurs Henry. Admiral Mouchez, in a communication to the French Academy, describes the apparatus which they employ, and states that by its aid a chart can be prepared in a single hour, which would require, by the ordinary methods, many months of assiduous labor.—*Comptes Rendus*, Aug. 18, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 6.—McDonough's Telephonic Inventions.

The pioneer work done by Reiss in the development of the articulating telephone, quite naturally attracted the attention of numerous investigators and inventors in different parts of the world, and resulted in the production of various forms of apparatus intended for the electrical transmission of speech Among the earlier investigators in this field the name of James W. McDonough occupies a prominent place.

McDonough came prominently before the scientific men in this country as a party to the famous telephone interference suits, declared in the United States Patent Office during the last eight or nine years. On the 10th of April, 1876, McDonough filed an application in the United States Patent Office for a "Teleloge, or a means for transmitting articulate sounds from one place to another through the medium of electricity." This application was placed in interference with the patent of Bell, dated March 7, 1876, and afterwards with the following applications; viz., that of Edison, of December 24, 1877; Dolbear, October 31, 1877; Richmond, August 24, 1877; Gray, October 29, 1877, and Holcombe, January 28, 1878.

The applications of the above parties, together with those of Berliner, Voelker, Blake and Irwin were placed in interference with Bell and with one another, and formed a long series of interference suits that have not yet been finally decided.

McDonough was admitted to the above interferences on the subject-matter of his receiver only. For reasons we shall afterwards refer to, he was excluded by the Office from participation in the other interference suits. The case in which he was a party was known in the Office as case G.

The subject-matter of this case was "Held to embrace a receiver containing an electro-magnet and a diaphragm supported and arranged in close proximity thereto, and adapted to respond to variations in the electric current passing through the coils of the magnet when used in connection or combination with a transmitter adapted to create sound-producing fluctuations in the electric current, whether said electrical variations, waves, pulsations, or undulations represent, or are derived from, sound-waves, or mechanical vibrations."

The above interference involved the extremely important issue as to the true inventor of the telephone receiver. After a long and thorough examination of the case it was decided by the Examiner in Interference cases by the awarding of priority of invention to McDonough. On appeal, however, to the Examiners-in-Chief, this decision was reversed and priority of invention awarded to Bell. The case is now on final appeal to the Commissioner of Patents, and awaits his decision.

Although the application of McDonough was made on the 10th of April, 1876, or after the issue of Bell's patent, of March 7, 1876, yet it was made before the date of Bell's lecture, May 10, 1876, or before the actual introduction or use of his articulating telephone. "So that," says the Examiner of Interferences, "McDonough's efforts in this direction may be regarded as entirely independent of and uninfluenced by Bell's disclosures and inventions."

Before describing McDonough's application of 1876, we will give a brief account of his experiments and inventions leading thereto.

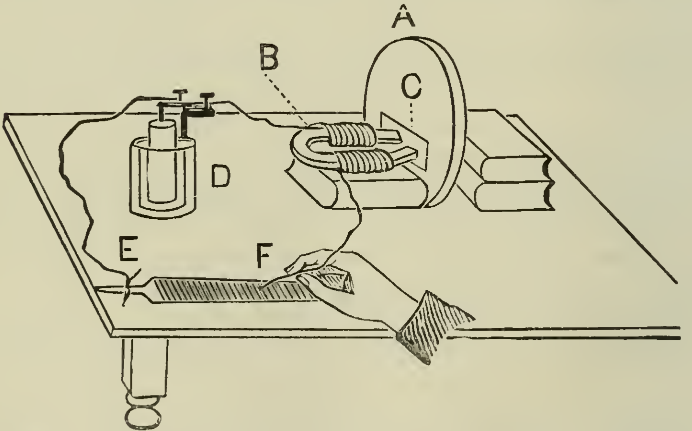


FIG. 1.—Apparatus of 1867, for obtaining Sounds by Interrupted Currents.

According to a sworn deposition made by McDonough in a telephone suit, his first experiments bearing on the subject of telephony were made in 1867, when he constructed an apparatus by means of which he was enabled to obtain a continuous sound by means of an interrupted current of electricity. This apparatus, which is shown in Fig. 1, consisted of a horseshoe electro-magnet *B*, placed before a paper diaphragm *A*, tightly stretched over an iron hoop. On the paper diaphragm, facing the poles of the horseshoe magnet, was attached a small piece of tinned iron *C*. The diaphragm and magnet were suitably supported on books and placed in the relative positions shown in the figure.

One terminal of a battery cell was connected with one of the terminals of the magnet coil, and the other terminal *E*, of the battery was wrapped around the end of an ordinary file *F*. When, now, the free terminal of the horseshoe magnet was drawn over the surface of the file, the makes and breaks thus effected in the battery current, produced fluctuations in the magnetism that corresponded with the fluctuations thrown on the electric current traversing the magnet coils, and thus produced movements in the diaphragm. A movement of contact, effected when the terminal touched the file, permitted the current to flow, and thus resulted in the attraction of the tinned iron to the magnet. A movement of the contact away from the file, causing a break in the circuit, permitted the diaphragm to move from the magnet in consequence of its elasticity.

With this early apparatus, McDonough was able to produce sounds that were audible at a distance of several feet from the diaphragm. The pitch of the sounds produced, of course varied with the rapidity of motion of the wire over the file.

Unfortunately McDonough does not appear to have preserved this early form of apparatus. All of it that remained in his possession in 1876, was the magnet, and the iron ring on which the paper diaphragm was stretched. Nor does he appear to have shown this experiment to others. At least he brings no witnesses to testify to having seen the parts assembled in the relations shown in Fig. 1.

Assuming, as we may fairly do, when taken in connection with subsequent apparatus that was shown to competent witnesses, that McDonough actually produced the combination of parts shown in Fig. 1, at the date alleged; viz., in 1867, then *great* credit is due him for the decided invention thus effected, since he has produced what may be fairly regarded as a new combination of parts whereby improved results can be obtained. For, when, at a later date, he placed such a magnetic diaphragm in combination with a telephone transmitter varied by the voice, he did much to place the articulating telephone in its present successful commercial position.

When we speak of the preceding combination of parts being novel when used to produce sounds by means of varied currents of electricity, we are not unmindful of the experiments of Page, in 1837, who obtained musical sounds from a magnet when an interrupted current was passed through a flat spiral placed between the poles. These early observations, which were confirmed by more extended experiments of De la Rive, and of Delezenne, were ascribed to molecular changes in the iron during its magnetization and demagnetization. In the McDonough experiment, the movements of the diaphragm producing the sound are not molecular, but mass vibrations. The entire diaphragm moves to or fro under the variations in the magnetic attraction. It is such a form of diaphragm that practice shows to be so valuable when used as a receiver for the articulating telephone.

McDonough does not appear to have done anything more with his apparatus than to have tried its capacity for producing sounds, more or less continuous, by the action of an intermittent current. Although he may have vaguely conceived the possibility of applying the apparatus to the transmission of articulate speech, yet such conceptions do not seem to have taken definite form until August 26, 1871, when he made the sketch that is represented in Fig. 2.

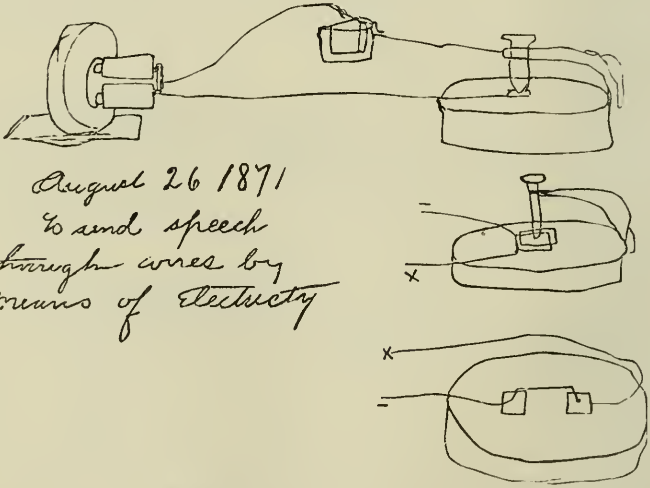


FIG. 2.—McDonough's Sketch of August 26, 1871.

This sketch, which was made in a memorandum book containing sketches and suggestions respecting some thirty different inventions, was the result of an idea conceived by McDonough after reading descriptions of the phonautograph, and of the Reiss telephone. The legend of the sketch, "To send speech through wires by means of electricity," clearly indicates the purpose of the apparatus. No other description accompanies the drawing, and in interpreting it we must bring to bear on it such a knowledge of the state of the art only, that it is fair to suppose was possessed by McDonough at the time he made the sketch. As to the apparatus shown on the left hand, its purpose is obviously the same as that of the experiment of 1867. The apparatus shown in the middle of the upper drawing is clearly a battery, since it is stated that the combination of parts is to be operated through the agency of electricity. As to the various forms of apparatus shown on the right hand of the sketch, they are apparently diaphragm-transmitters of the Reiss type, designed to be used in the manner fully described by Reiss. Moreover, the apparatus shown in the lower, right hand sketch is substantially the form of transmitter figured in his application of April 10, 1876. Since McDonough was acquainted with the experiments of Reiss, and had experimented as to the ability of a magnetic diaphragm to be set into motion by means of a varied electrical current, it is fair to suppose, admitting the credibility of the sketch, that he intended to combine his magnetic diaphragm, with a voltaic battery and a modified Reiss transmitter.

McDonough does not appear to have actually embodied his invention in a working model until the latter part of May, 1875. This delay was owing to ill health, change of residence, and great press of other business. In May, 1875, however, he constructed his first telephonic apparatus.

The membranes of the transmitting and receiving instruments were stretched over the ends of two cylindrical tin cases. A piece of tinned iron was fastened on the diaphragm of the receiving instrument, and the poles of an electro-magnet were placed in proximity thereto. Near the centre of the diaphragm of the transmitting instrument was secured a small piece of tin foil. This diaphragm was suitably supported in a horizontal position. A needle, passing through a glass tube supported in a vertical position over the diaphragm, rested with with its lower end on the plate of tin foil. The needle was free to move up and down, and formed one of the terminals of a battery, the other terminal being connected with the line. This form of apparatus was somewhat modified in June, 1875, when the form given to it was as shown in Fig. 3.

In this form of apparatus the tin foil was replaced by a small plate of German silver. *A*, represents the tin-can receiver, with its diaphragm, *C*, and plate of tinned iron, *E*. The electro-magnet, *F*, is adjustable with reference to the diaphragm. The transmitter consists substantially of the tin can, *B*, on the diaphragm of which is placed the German silver plate, *H*. The glass tube, *J*, contains the contact needle. The connections with the battery, *G*, are as shown. With the preceding apparatus, familiar tunes were successfully transmitted, but no words.

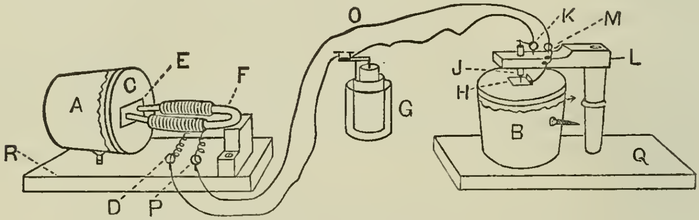


Fig. 3.—McDonough Telephonic Apparatus of June, 1875.

Fig. 4, shows the details of a modified form of apparatus constructed by McDonough later, in June, 1875. The membrane, *A*, is stretched over an iron hoop. *B*, is an iron plate, fastened to the diaphragm. The electro-magnet, *C*, is securely mounted, in the position shown, on an adjustable standard.

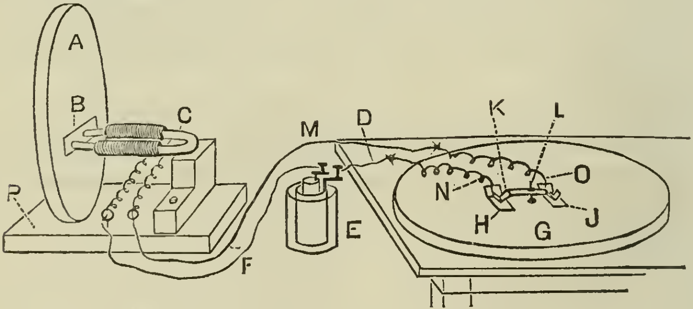


Fig. 4.—McDonough's Later Telephonic Apparatus of June, 1875.

The transmitter consists of a parchment diaphragm *G*, stretched over an iron hoop or ring. Two metal plates, *H*, and *J*, of German silver, are securely attached to the diaphragm, about an inch and a half apart and connected with the wires, *N*, and *O*, as shown. A light strip of metal, *K*, bent in the form shown, rested on the metallic plates, *H*, and *J*, and completed the electric circuit between them. The bolt, *L*, with a nut for adjustment, was subsequently added in order to prevent the vibrations of the diaphragm from moving the metallic bridge, *K*, away from the metal plates, *H*, and *J*. One of the above mentioned iron hoops was the one employed in the experiment of 1867.

The above apparatus, which was completed about the middle of June, 1875, was successfully employed for the transmission of articulate speech on many occasions during the same month. A number of witnesses testify to having heard articulate speech by the use of the preceding instruments.

Only parts of the apparatus of June, 1875, were preserved. These were used as exhibits in the United States Patent Office interference case with Bell and the other parties mentioned. The instruments, however, were reproduced with all the exactness possible, and are represented in Fig. 5. This apparatus has been successfully used by several parties for the transmission and reproduction of articulate speech.

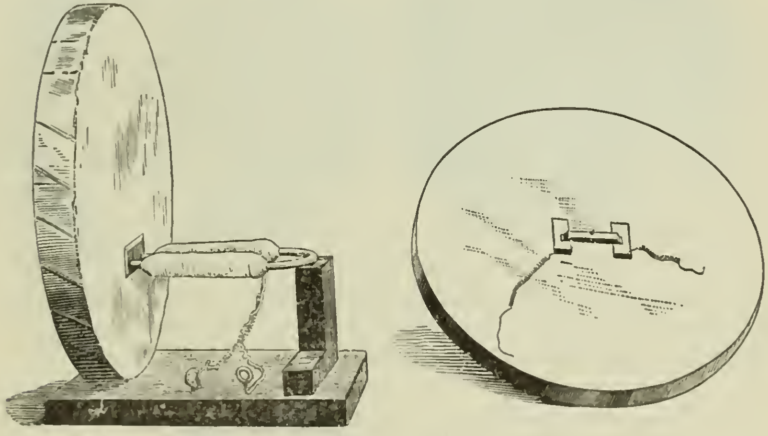


FIG. 5.—Reproductions of McDonough's Telephone of June, 1875.

Having satisfactorily shown the capability of his instruments to transmit articulate speech, McDonough set to work to improve the strength of the sounds reproduced by the receiver. Prior to the filing of his application for a patent on the 10th of April, 1876, he constructed and carried on numerous experiments with some fifteen different instruments, frequently interchanging the transmitters and the receivers.

We will describe a few of the more important of these early forms of articulating telephones. Fig. 6, shows an instrument constructed and used by McDonough in September, 1875.

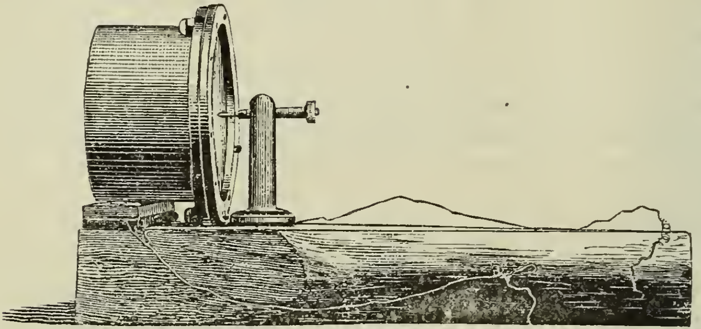


FIG. 6.—McDonough's Metallic-Diaphragm Transmitter, September, 1875. (Exterior.)

The diaphragm in this instrument is mounted on a brass cylinder, and unlike the previous diaphragms, is metallic, being made of a thin sheet of German silver. The arrangement by means of which the diaphragm is firmly clamped in position on the end of the brass cylinder, is shown in the drawing. Directly opposite the centre of the diaphragm an electrical conducting cylinder, or electrode, was supported so as to be in contact with the diaphragm at one of its ends. This electrode was supported by the vertical post placed in front of the diaphragm, and was furnished with an adjusting screw so as to permit its position as regards the diaphragm to be varied at pleasure. The too free vibration of the diaphragm was prevented by means of a screw whose bearing was in a transverse bar. This clamping device is shown in a rear view of the same apparatus in Fig. 7.

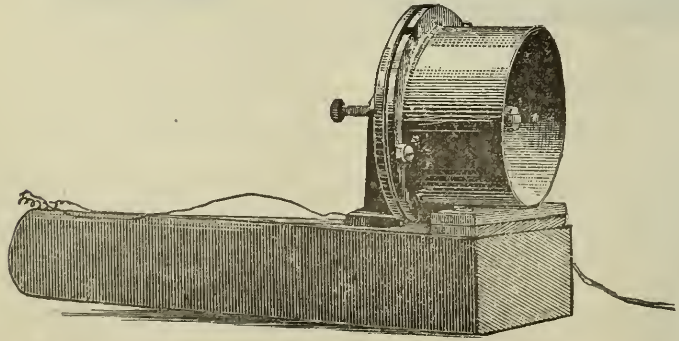


FIG. 7.—McDonough's Metallic-Diaphragm Transmitter, September, 1875. (Interior.)

One of the circuit wires was connected with the metallic diaphragm and the other with the contact electrode. Various materials were employed for the contact electrode, such, for example, as nickel, German silver, platinum, steel and carbon. The latter, which appeared to give the best results, was formed of the graphite of an ordinary lead pencil.

The transmitter of September, 1875, was used in connection with the receiver of June, 1875, as well as with other receivers.

A later form of transmitter and receiver were constructed by McDonough in October, 1875, and named by him "The tin-drum pendulum" instruments. These instruments are shown in Fig. 8.

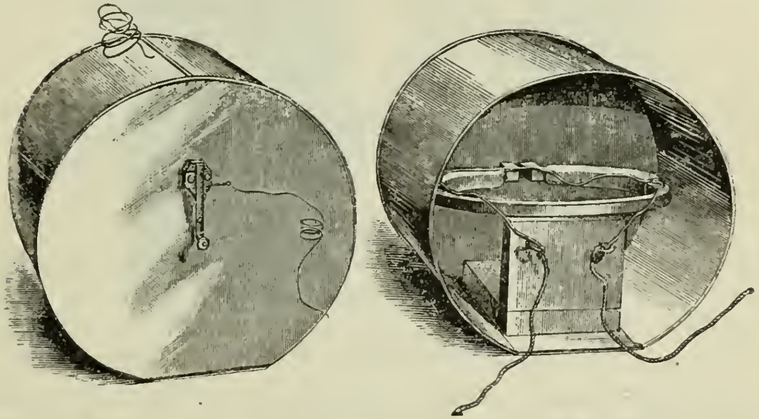


Fig. 8.—McDonough's Tin-Drum Pendulum Transmitter and Receiver, October, 1875.

The transmitter of this set of instruments consisted of a tin-drum or cylinder flattened on one side, and enclosed at one end, which formed a diaphragm; at the centre of this diaphragm a small piece of platinum was soldered and formed a contact point for an electrode, which, as before, was formed of various materials such as platinum, steel, brass or carbon. The electrode was "inserted in a socket formed in the end of an adjustable screw, which was carried by a hinged pendulous bar of brass, about two and one-half inches in length. The pendulous bar was so hinged as to press the electrode in towards the platinum." The details of this device will be the better understood from an inspection of Fig. 9, which shows another view of the transmitter. The hinged end of the pendulous brass bar was supported on any insulating material. One terminal of the line was connected to the pendulous bar and hence to the contact electrode, and the other end to any part of the tin-drum, and therefore to the platinum plate.

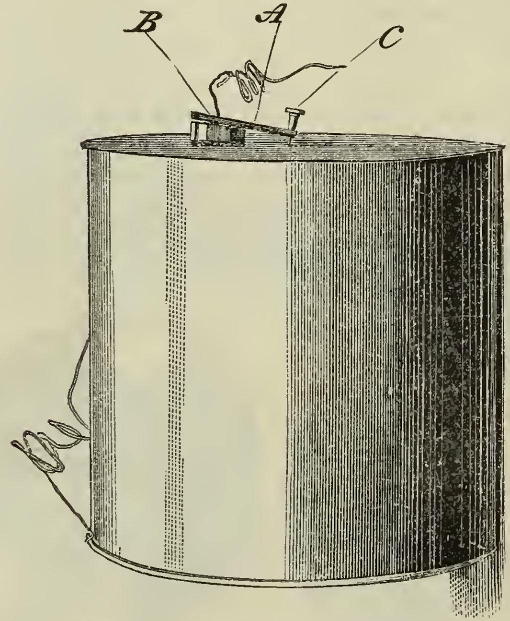


FIG. 9.—McDonough's Tin-Drum Pendulum Transmitter.

The receiver, which is shown on the right hand in figure 9, consisted like the transmitter, of a tinned-iron cylinder, closed at one end, and flattened on one side. Inside the cylinder, suitably supported on an upright stand, was placed an electro-magnet, with its poles in close proximity to the tinned-iron diaphragm.

The above instruments successfully transmitted and reproduced articulate speech, but, as might be supposed, the resonance of the apparatus somewhat interfered with the distinctness of the articulation.

A subsequent set of instruments known as "The Brass-Drum" instruments, are shown in Fig. 10.

A brass cylinder *A*, has a membrane tightly stretched over one of its ends by means of the tightening ring *B*, and the adjusting screws *C*, An adjusting screw and its socket-electrode are placed, as shown at the centre of the diaphragm. A wooden ring *G*, is provided for supporting the tightening ring and diaphragm. The instruments rest on the under base *H*. The hinged doors in the instruments are provided for adjusting of an electro-magnet placed inside each drum, with its poles near a metal plate secured to the under side of the diaphragm. As in the previous instruments, various forms of electrodes were employed in connection with the adjusting screw. Since each of these instruments was provided with an electro-magnet, either could be employed alternately as transmitter and receiver.

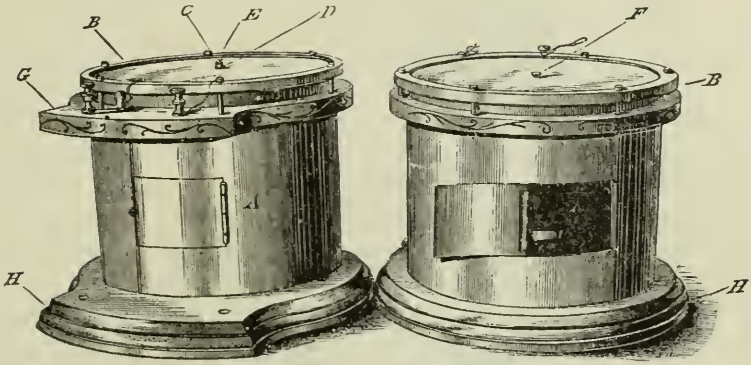


FIG. 10.—McDonough's Brass-Drum Telephone.

Having thus briefly traced the progress of the invention as claimed by McDonough, and testified to by competent witnesses, we will now discuss the apparatus which was described and figured in connection with his application in the United States Patent Office, on the 10th of April 1876, together with the working model that accompanied said specification. The drawings that accompanied this specification are shown in Fig. 11.

"In Fig. 1," is shown a perspective view of the "teleloge."

"Fig. 2," represents a section taken on the line *xx*.

"Fig. 3," represents a vertical transverse section taken on the line *yy*.

"Fig. 4," is a general top view of the same.

Quoting the language of the specification: "The object of my invention is to provide a means for transmitting articulate sounds from one place to another, through the medium of electricity, and it consists in the combination with an electrical battery, circuit wires, armature, magnet, and circuit breaker, of a transmitting and a receiving membrane or sounding apparatus, so constructed as to vibrate in accord with the vibrations of articulate sound, and so arranged relative to the magnet and circuit-breaker that the vibrations of the transmitting membrane or apparatus, produced by articulate sounds, are transmitted by the electrical current to the receiving membrane or apparatus, and so as to cause a like vibration of the receiving membrane or apparatus, and to cause it to reproduce the articulate sounds transmitted from and by the transmitting membrane or apparatus. My invention also consists in the novel construction of the circuit breaker, as is hereinafter more fully described."

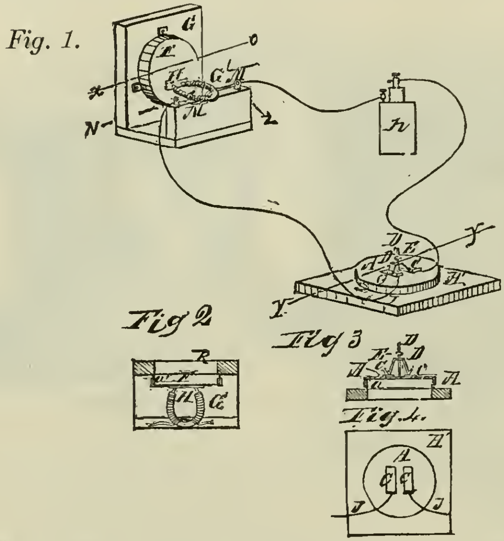


FIG. 11.—McDonough's Drawings accompanying specification of Letters-Patent for a "Teleloge," filed April 10th, 1876.

Then follows a description of the drawing. The transmitting membrane or diaphragm, shown at *A*, is composed of vellum or other suitable material so stretched over a metal hoop, or ring *a*, as to be capable of being tightened or loosened as desired. *C*, *C*, are two metal plates attached to the upper surface of the diaphragm, near its centre, in the relative positions shown, and are suitably insulated from each other. The metal bolt *D*, permanently attached at its lower end to the centre of the diaphragm, between the two plates, and insulated from them, passes through an opening in the middle of the arch-shaped circuit-breaker *D′*, and is furnished with an adjusting nut *F*, that serves the purpose of limiting the movements of the circuit-breaker *D′*. The circuit-breaker *D′*, consists af an arch-shaped piece of metal loosely secured at its centre on the bolt *D*, and having its extremities bent upward at each end so as to provide contact surfaces that rest on the metal plates *C*, *C*.

The receiving instrument consists of a diaphragm of vellum or other suitable material "sensitive to the vibrations of sound," stretched on a metal hoop or band a^1, in the position shown. An electro-magnet G^1, is placed with its poles opposite an armature *H*, attached to the surface of the diaphragm.

The circuit connections are as follows; viz., one wire from the battery *h*, is connected with one of the metal plates *C*, and the other with one end of the coil of the electro-magnet of the receiving instrument. The other plate *C*, is connected with the remaining terminal of the electro-magnet G'.

The operation of the apparatus as described by the inventor is as follows, viz.: "The transmitting membrane *A*, being sensitive to the vibrations of articulate sounds produced thereon, is caused to vibrate in sympathy therewith, thereby imparting an upward movement to the circuit-breaker at each vibration, disconnecting it from the plates *C*, *C*, and alternately breaking and closing the circuit, when the intermittent current alternately magnetizes the magnet G', attracting the armature *H*, and causes it, and the membrane *F*, to vibrate simultaneously with the vibrations of the transmitting membrane *A*, and in accord therewith, and so that the membrane *F*, reproduces the articulate sounds transmitted from and by the membrane *A*."

The working models accompanying this specification were destroyed in the fire at the Patent Office. A duplicate set of instruments was subsequently made and deposited in the Patent Office in lieu of those destroyed. Another set of duplicates was also made for examination and trial by experts. The details of these models are shown in Fig. 11.

We have already called attention to the fact that the above application was put in interference with Bell and the other applicants in the matter of the receiver only. This circumstance was due to the fact that the U. S. Patent Office held to the belief in the "undulatory current theory" as being essential to the transmission of articulate speech. It argued that speech could not be transmitted by make and break currents, and that since McDonough's apparatus decribed such currents it could not be considered as an articulating telephone transmitter. This singular process of reasoning, which was perhaps only the natural result of an unhesitating acceptance of a theory which can by no means be regarded as unquestionably proved, was maintained despite the fact that the model deposited in the office with the specification and drawings, together with the other apparatus we have described, could and did transmit intelligible, articulate speech, as has been amply testified by experts of unquestionable integrity and ability. No question, however, appears to have been raised as to the ability of the receiving instrument to reproduce sounds of all kinds, including intelligible, articulate speech, so that the Examiner of Interference awarded the priority of invention on this count of the interference to McDonough, above all the other contestants.

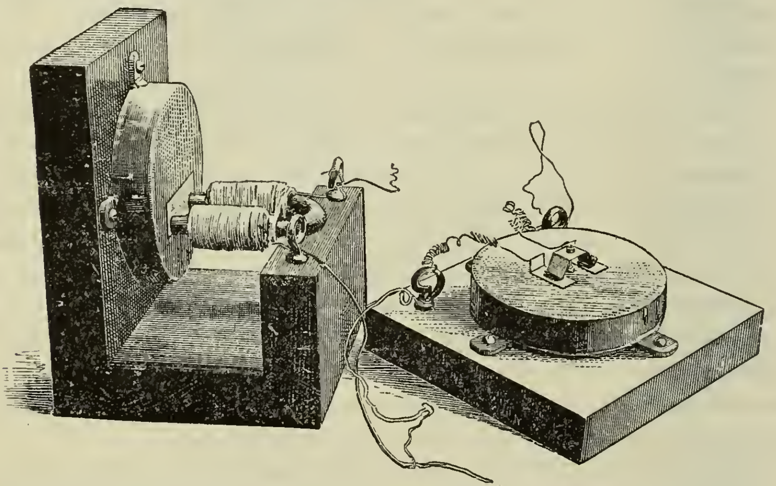


FIG. 12.—McDonough's Patent Office Model, Transmitter and Receiver, April 10, 1875.

The subject-matter of the interference in case *G*, on Gray's claim, application of October 29, 1877, is as follows, viz.: "A telephonic receiver consisting of the combination in an electric circuit of a magnet and a diaphragm supported and arranged in close proximity thereto, whereby sounds thrown upon the line may be reproduced accurately as to pitch and quality."

In the printed record containing the decision of the Examiner of Interferences it is acknowledged that a diversity of opinion exists as to the scope of this claim, and the interference founded thereon. It is claimed, on the one side, the designation, "A Telephonic Receiver," together with its prescribed capacity, "whereby sounds thrown upon the line may be reproduced accurately as to pitch and quality," is tantamount to a claim for the combination of such receiver with an instrument capable of producing electrical waves or undulations bearing the impress of sound waves."

"On the other hand, it is maintained that the claim is to a described combination of these elements; an electric circuit, a magnet, and a diaphragm; the parts being so disposed and arranged as to manifest, among other functions, the capacity to reproduce sonorous vibrations electrically transmitted, and that the particular means for creating the electric current which is to be translated into sound-vibrations form no limitation upon the invention."

The Examiner-in-Interferences adopted the view that the issue embraced the telephone receiver alone, and on this construction of the issue awarded the priority of invention to McDonough. The Examiners-in-Chief, however, to whom, as we have already remarked the case was appealed, adopted the view that the issue clearly necessitated the combination with the receiver of a transmitter capable of throwing on the line the peculiarities of articulate speech. On the assumption that a transmitter constructed as was that of McDonough's could not transmit articulate speech, and that therefore the combination of such a transmitter with a diaphragm receiver was not effected, the Examiners-in-Chief, awarded the priority of invention to Bell. The above, as we have already remarked, was the natural conclusion, in view of the belief of the Examiners-in-Chief, as to the necessity for an undulatory current for the transmission of articulate speech.

There appears to be ample testimony by the most able experts that apparatus constructed in accordance with the McDonough specification of April 10, 1876, can and does clearly transmit intelligible articulate speech. McDonough's apparatus combines with a magnetic diaphragm receiver, what may, perhaps, be regarded as a variety of Reiss transmitter. If then it be admitted that the Reiss transmitter had never previously transmitted intelligible articulate speech, which we deny, then since it does transmit it when coupled with a magnetic diaphragm receiver, it might appear that the essence of the invention of the articulating telephone consisted in the invention of a suitable receiver to be used in combination with a Reiss transmitter.

No little probability would appear to be given to this view, from the generally acknowledged fact that the Reiss transmitters operate very satisfactorily when combined with magnetic diaphragm receivers.

It is, indeed, in our opinion, an open question whether the real improvement in the art that placed the telephone as left by Reiss in the extensive commercial use it now has, did not in reality consist rather in the invention of a more suitable receiver than it did in any modification the Reiss transmitter has since received. We can readily understand how a current, modified by the action of the human voice on a Reiss transmitter, would produce in a magnetic diaphragm such undulations in its magnetic field as would result in the movements necessary to reproduce the articulate speech thrown on the transmitter.

Such a view, it will be seen, takes the assumed necessity for the undulatory character, in the somewhat narrow sense in which it is generally construed, from the electric current transmitted, and places it in the transmitting and receiving diaphragms, so that the movements of the receiving diaphragm would still be an exact reproduction of those of the transmitting diaphragm.

When describing the inventions of Reiss, we will discuss at greater length the peculiarities of the electrical currents transmitted in telephony.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, February 14, 1885.

PHYSICAL CONSTITUTION OF THE SUN.*

BY PROF. CHARLES A. YOUNG.

The lecturer was introduced by Dr. WILLIAM H. WAHL, Secretary of the Franklin Institute, who said:

LADIES AND GENTLEMEN:—Professor Charles A. Young, Past President of the American Association for the Advancement of Science, will lecture to you this evening on the "Physical Constitution of the Sun." It is hardly necessary for me to remark that there is no physicist in this country more competent to discuss this subject than Professor Young, whom it affords me great pleasure to introduce to you.

PROFESSOR YOUNG:—Ladies and gentlemen, I am going to begin, not with an apology† exactly, but something a little like one. It is no fault of mine in the matter, but I am afraid I shall find it difficult to make you hear me this evening on account of the acoustic character of the room. I will do my best, however, and that is all any man can do.

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* A Lecture delivered at the International Electrical Exhibition of the Franklin Institute, September 25, 1884.

† The peculiarly bad acoustic character of the lecture-room, made it necessary to speak in short and disjointed sentences, with many repetitions, in order to be understood at all by the remoter portions of the audience. The lecturer hopes that the reader will make due allowance for this, as accounting for the awkward literary form of the address.

The subject I am to speak about I am sure will interest you. The sun is the life of us all; it keeps the world going. All terrestrial energy is but solar energy at second-hand. I will not discuss this evening the distance of the sun, its dimensions, etc., and the methods of ascertaining them, although I might make a very interesting lecture from that point of view, but I will begin at once by stating a few facts, which are essential to an understanding of the sun's constitution.

In the first place, then, the size of the sun is something enormous, absolutely beyond our power of conception. It is a great ball about eight hundred and sixty thousand miles in diameter, or one hundred and ten times the diameter of the earth. Perhaps that means nothing to you; but just for a moment imagine yourself in the centre of the sun, if it were possible for you to live there. Suppose the earth were placed in the centre of the sun where would the moon come? Why, it would only be a little more than half way to the solar surface. If the earth were at the centre of the sun, the moon would circle around the earth about half way from the centre of the sun to its surface. The radius of the sun is about four hundred and thirty thousand miles, and the distance of the moon from the earth is only two hundred and forty thousand miles, so that if we lived in the centre of the sun, its shell would make an admirable sky for all the lunar motions. Next, the sun is about a million and a quarter times the bulk of the earth. Take one million three hundred thousand earths and roll them into one ball and it would make a sphere about the size of the sun; but, the sun is not correspondingly massive, for it is only about three hundred and thirty thousand times as heavy as the earth. It follows, of course, that it is not as dense as the earth; it is only about one quarter as dense, or a little more than the density of water. A bushel of sun would weigh only about a quarter as much as an average bushel of the earth.

The sun, therefore, cannot well be a solid substance; it is not a ball of rock like the earth, but probably a great bubble as we shall see further on; a mass of gases surrounded by a shell of cloud.

Its power of attracting bodies is very great of course, because its mass is so enormous. On the surface of the sun a body would weigh nearly twenty eight times as much as on the earth, so that if I were on the surface of the sun I should be crushed. I could hardly lift my hand to my head for the force of gravity would be twenty-eight times as strong as it is here, and it would increase the weight so that a pound here would weigh twenty-eight pounds there. Of course you will see at once that this is a very important fact, as bearing on the constitution of the sun.

The solar ball rotates upon its axis just as the earth does, but more slowly. The earth turns around in twenty-four hours, but it takes the sun about twenty-five days to make one rotation. Now a very characteristic thing in regard to the sun's rotation is that it does not go all together; the equator of the sun, or its central zone, makes its circuit in about twenty-five days, but at a point half way to the poles it takes some twenty-seven days, or two days longer. It is as if the day on the earth at the mouth of the Amazon river were about two hours shorter than at the mouth of the St. Lawrence. The revolution of the sun's equator is more rapid than that of other portions, so that different portions of the sun appear to drive by each other like eddies in a stream. The sun's surface is not a solid mass, but like clouds, and the different portions are not coherent or strongly attached to each other.

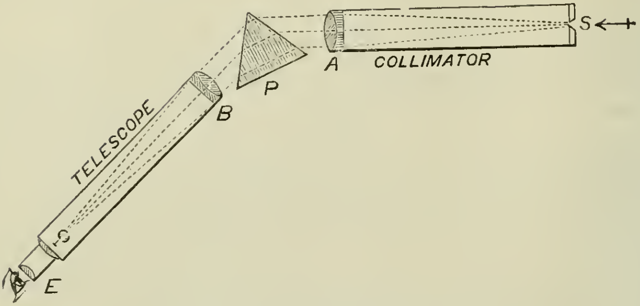
What we know about the sun comes almost entirely by the way of its radiance, or the light and heat, that it sends us. I am not going to give you a lecture on the nature of this radiance; a far more competent authority, Sir William Thomson, will treat that subject in the Academy of Music next Monday night. But I suppose you all know that the energy of the sun reaches us almost entirely in the form of waves, somewhat like the undulations of sound, which start from the sun and reach us here just as the waves of sound go through the air from me to you. These waves of solar radiance differ from each other only in the same kind of way that sound waves differ; in pitch and energy, but in nothing else. There is no proper distinction between sun-heat and sunlight, they are only different forms of the same action. The same radiance precisely, if it falls on my eye will make me see, and if it falls on a black sheet of paper will make it warm; while if it falls on a chemically prepared plate it will produce a picture by its chemical action. There is no line of distinction to be drawn between the light, heat and chemical rays. A few years ago it was believed that there were such differences, and the distinction still remains in some of our old text-books where you will find solar light, heat and chemical energy contrasted with each other in a way that is now known to be untrue and very mischievous.

The way to analyze sunlight is to take it to pieces by some form of instrument, and for this purpose we use the spectroscope.

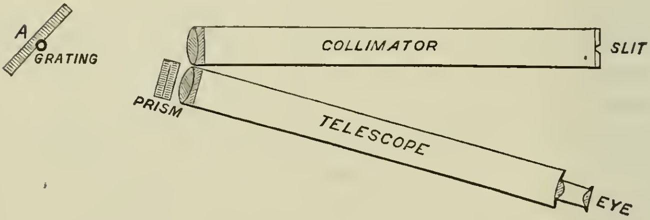
Now its construction and action will be most easily exhibited and explained by throwing upon the screen lantern-pictures illustrating the matter, and we have all the arrangements ready for doing this as soon as the room can be darkened. I will, however, in order to fix in your mind what I have been saying about the size of the sun, first show upon the screen a picture which will show the dimensions of the sun in comparison with the planets, and afterwards the other pictures, showing how we decompose the sunlight to find out of what the sun consists. While the room is being darkened I will say that this taking to pieces of sunlight and examining its parts and details is a comparatively new invention. It was found about seventy-five years ago that the spectrum that Sir Isaac Newton discovered, more than two hundred years ago, had markings upon it; and about twenty-five years ago it was found that they are full of significance, enabling us to tell of what materials the sun is composed. In looking through a spectroscope directed to any source of light, you will see in it a colored ribbon red at one end and violet at the other. If you should look at one of these incandescent lights the ribbon would be perfectly unmarked and smooth; but if the instrument were turned toward one of the arc lights the spectrum would be crossed by bright bands and lines; while if turned to the sun it would show a band marked by fine dark lines.

On this diagram now thrown upon the screen you have a representation of the sun with its planets around it drawn to scale. I presume you recognize the great planets Jupiter and Saturn and the earth we live on, so that you can get a true idea of the relative proportions of the sun and its attendant worlds; the earth you see, is a mere speck in space, although it affords room for a great many human beings.

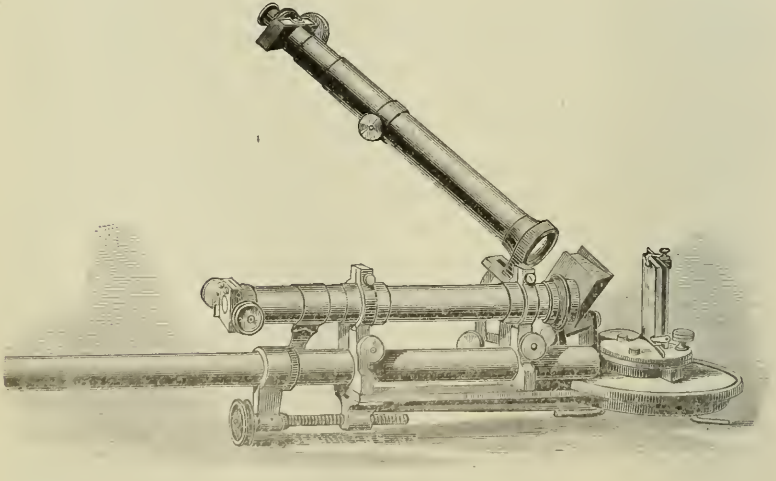
This next picture shows an ordinary spectroscope. The light enters the tube by a little slit at the further extremity not more than a thousandth of an inch wide and perhaps one-eighth of an inch long. This slit is at one end of a tube marked "collimator" as you see; at the other end is a lens of focal length just equal to the length of the tube. The light which passes through the slit has to traverse this lens before reaching the prism, and the effect of the lens is to render the rays parallel just as if they came from a star. Optically speaking, the collimator lens puts the slit off in the sky—at an infinite distance, while at the same time it leaves it at the ends of your fingers. The light



Arrangement of Prismatic Spectroscope.



Diffraction Spectroscope.



Princeton Spectroscope.

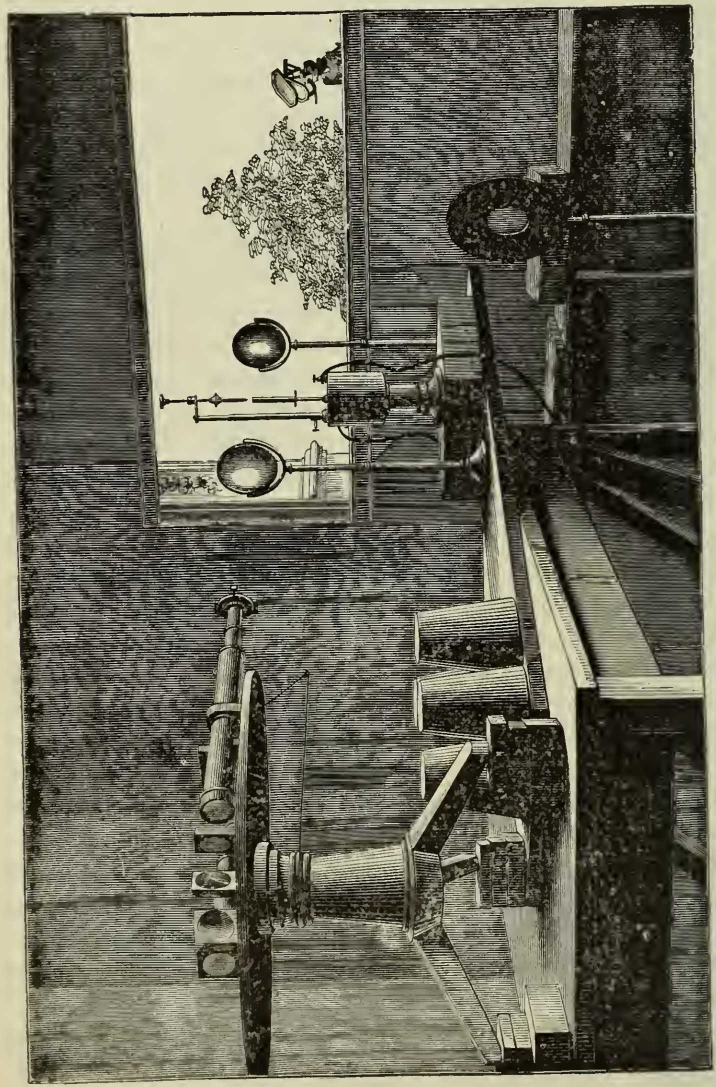
goes through a prism which changes its direction; then it goes to the view telescope and looking through that you see the ribbon of light.

In the second form of the apparatus shown on the lower part of the screen we have the same thing essentially, but different in detail. We have a collimator just as before, but after passing this the light strikes upon what is called the grating instead of a prism. There are some beautiful specimens of gratings exhibited in the next room. A grating consists of a flat polished mirror ruled with parallel lines drawn close together, many thousand in the inch.

The light then goes to the eye through the view telescope, and the grating produces the same effect and gives you a spectrum precisely as a prism would do. The instrument I throw upon the screen is the spectroscope which I use in Princeton with one of our telescopes there. The slit is here (pointing) at one end of the collimator tube; the grating stands upright at this place. Here is the telescope into which we look. The actual size of that particular instrument is about one and a half feet in length. I sometimes use another on which the collimator is four feet long, and the grating is six inches by five inches. It was ruled by Professor Rowland of Johns Hopkins University, Baltimore, with some eighty thousand lines, by a most beautiful and perfect apparatus of his own invention. That gives a longer spectrum than you obtain by the smaller instrument.

I show you now an apparatus which Mr. Lockyer uses in taking photographs of the spectrum. The light first comes through a window and passes through the further one of these two lenses and goes to where you see an electric lamp; then it passes through these lenses and to the spectrum; then through the prisms of the spectrum and thence to the camera box so that a photograph of the sunlight spectrum can be taken. You then shut the window and start the electric light, giving a spectrum which you can also photograph. If you put in the lamp a piece of iron or sodium or copper, you can thus compare the spectrum of sunlight with that of the substance which is put into the electric lamp.

Before showing Mr. Lockyer's results, I first throw upon the screen some spectrum photographs made by Professor Rowland. Here is a little portion of the blue part of the spectrum; the blue color is of course absent in the photograph. What I want you to notice line is the great number of lines. I have marked one "h"; that



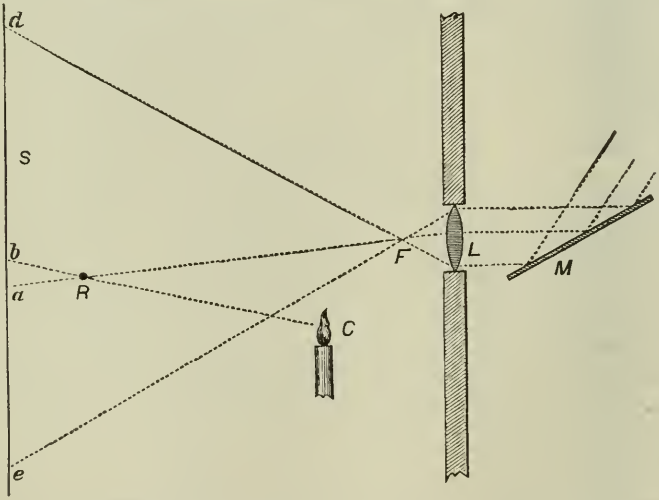
General Arrangement of Spectrum Photographic Apparatus.

is due to hydrogen. This double line (pointing) is due to the presence of iron in the sun, and so of the other lines. We know the chemical elements which produce about half of these lines; the other half have not yet been identified. Now we show a piece of the green portion of the spectrum, a very important part of the spectrum it is too. This is interesting to photographers if there are any in this room; because all photographers know it is quite difficult to photograph green light. In that photograph it is possible to see about everything that it is possible to see by the naked eye in the spectrum. The photograph is so perfect that excepting only the color you can see all that can be brought out in the spectrum, by the most powerful instruments in use. One of these particular lines happens to interest me especially; that line (pointing) is the line which characterizes the spectrum of the corona. It is known as the 1,474 line, because it happened to come in that place in a map of the spectrum much used, made at an early date. It proves that the corona is largely a mass of floating gas.

By putting side by side the spectrum of the sunlight and the spectrum of iron we can determine the presence of iron in the sun, and here is original evidence of the fact. This picture was originally taken by Lockyer with the apparatus I have shown you, and was made in the way I have described to you. The upper part of this is a negative of the spectrum of iron. Bright lines of course show black in the picture, so that every one of these black lines represents a bright line in the spectrum of iron. Now look at the lower portion of the spectrum. That is a spectrum of sunlight. These white lines are dark lines in the solar spectrum. There is no further need of my telling you that iron is in the sun; for do you not see that every one of these iron lines has its representative in the solar spectrum? Take the three at the lower end. Here is a double line, it is double in the solar spectrum. There are many lines in this solar spectrum that are not lines of iron lines, but there is not an iron line that is not in the spectrum of the sun. If I should write "iron," it would not spell iron more plainly than do these lines. We have the same sort of evidence in relation to other materials, so that we can say with confidence that these metals exist in the sun.

I have not time to explain to you how bright lines in the spectrum become dark lines in the solar spectrum. If I take a vapor giving a spectrum of bright lines and put a stronger light behind it then these bright lines will be reversed and they will immediately turn black, but I must not stop to tell you why.

This next slide gives you the catalogue of the solar elements so far as we know them. Iron, titanium, calcium, etc.; going down the list until you get to this point, there is not a substance known to exist in the sun that is not metallic. Nitrogen and chlorine do not show themselves there, carbon does not appear; many of the elements which are most powerful on the earth seem to be entirely wanting. What it means scientists cannot tell. There are many hypotheses, many theories, one being that the elements there represented are really more elementary, more difficult to be decomposed than nitrogen and chlorine; it being taken for granted that these elements are not elementary at all, but that they are decomposed by the great heat of the sun. We find metals and for the most part nothing else in the sun; perhaps sulphur is there, but probably not; oxygen, however, is probably present, indicating its presence very peculiarly by certain *bright* bands and lines first brought out by the photographs of Dr. Henry Draper some seven or eight years ago.



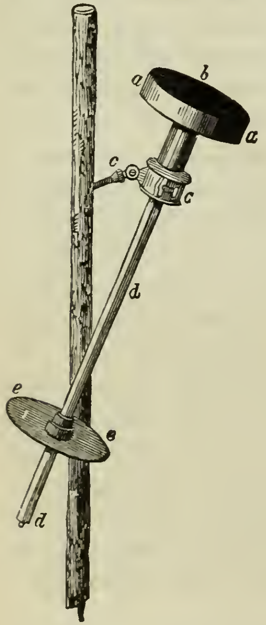
Method of Measuring the Intensity of Sunlight.

Passing now to the strength or intensity of sunlight, the picture before you is intended to show how we measure this. We find that the sunlight is equivalent to about one thousand five hundred and seventy-five billions of billions of candles, and this diagram roughly represents the apparatus by which we determine that fact. It is done in this way; the sunlight shines on a mirror, and so is reflected into a room through a lens of known size, say one inch in diameter. The rays after passing the focus diverge and fall on the screen; if the image on the screen is ten feet, or one hundred and twenty inches in diameter, you will see that the light will be reduced fourteen thousand four hundred times; if we make the diameter of the disc twenty feet, we reduce the light a great deal more, four times as much; making it still larger, we reduce it more yet, and in that way we easily reduce the sunlight to the one hundred thousandth part of its natural strength. Now by moving the candle *C* we can get the shadow of the pencil *R*, cast by the sun shining through that lens, of the same darkness as that cast by the candle; and in that way we can compare sunlight with candlelight; and we find what I have before stated.

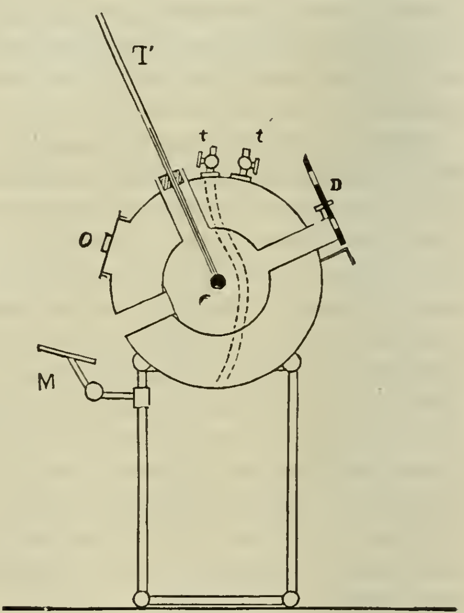
When you consider the brightness of the sun's surface you find it to be about one hundred and fifty times as bright as one of our calcium lights, and about four times as bright as the brightest of the points in one of our electric lights. The electric light is very bright, but the solar surface is about four times as bright as that. Some of you have seen the Bessemer process of making steel; Professor Langley compared sunlight to the light from the surface of the molten steel. He made the comparison through the smoky air of Pittsburgh purposely giving every advantage to steel, and stealing every advantage he could from the sun, and yet under those circumstances the solar surface shone more than five thousand times more brightly than the surface of the steel. Every square foot of sun was giving more than five thousand times more light than the steel surface; and considering the unfavorable circumstances it was probably giving ten thousand times more light.

Let us pass now to the consideration of the amount of the solar heat. One of the earliest apparatus for measuring it is shown here on the screen and is called a pyr-heliometer, *i. e.*, measurer of solar fire. It is a sort of snuff box of thin polished silver, blackened on the front surface and filled with water. In the box a thermometer bulb is placed, the mercury marker standing at the point "*d.*" It is turned towards the sun, and the sun is allowed to shine on the upper surface of the box so as to warm the contained water, and it is observed how much the sun's rays will warm it in a given time. It is allowed to stand, say, five minutes to see how much change the temperature will change, first with an umbrella over it to shut off the light, and then with the sun striking fully upon it, and thus we find how much a given beam of light will raise the temperature of a given weight of water.

Other forms of instruments are made. Here is one that Violle has used. It is a hollow sphere containing a thermometer around which water is circulated in a jacket. The sun is allowed to shine through the open space and the thermometer will rise until it is some 18 or 20 degrees higher than a thermometer outside. If you know just how much higher you can calculate just how much heat is received from the sun.

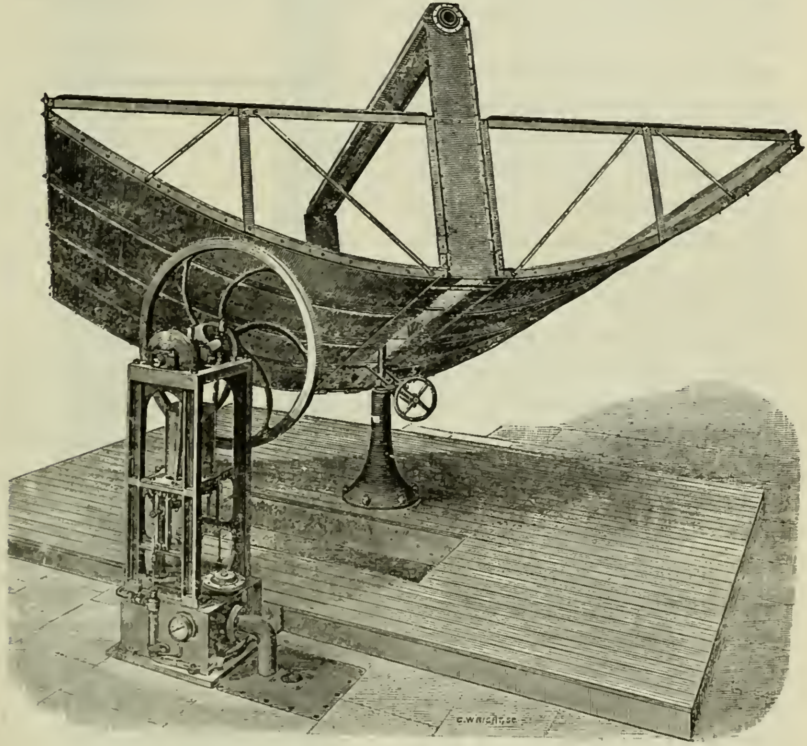


Pouillet's Pyrheliometer.



Violle's Actinometer.

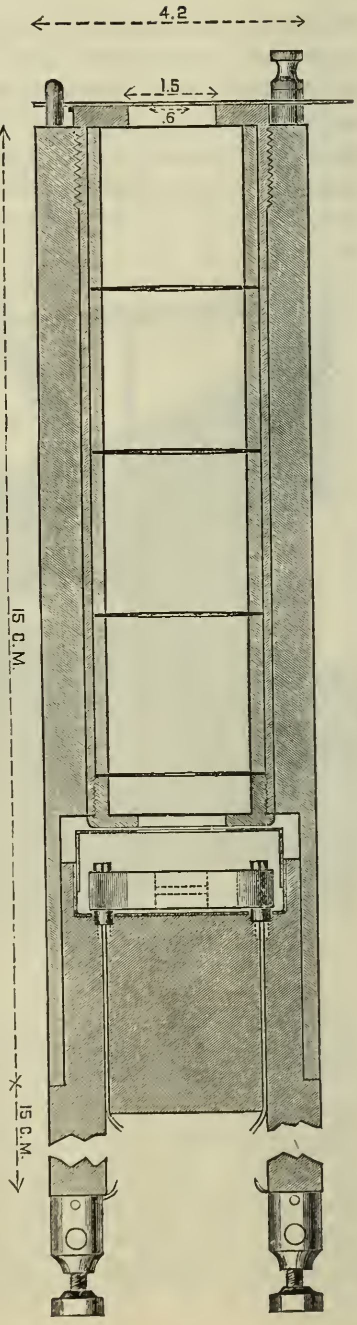
The apparatus shown in this picture is a solar engine invented by Mr. Ericsson a year or two ago. It is possible to collect the sun's rays in a great mirror like that and throw them on a hollow tube of iron about six inches in diameter and twelve feet long and filled with water. The heat of the sun sets the water boiling and that is connected by a pipe with a steam engine which is thus driven by the solar heat. Upon thirty square feet of the earth's surface enough sun heat falls to give pretty nearly a continuous horse power, *i. e.*, if you could collect all the heat on that amount of surface you would have a horse-power of heat, and this heat would enable you to drive an ordinary engine of about $\frac{1}{6}$ of a horse-power. During the present summer the haze in the air has diminished the effectiveness of the heat. You can see that an engine of that kind would be of considerable value in a rainless country like Egypt or our western regions, where very much work could be done by the rays of the sun directly.



Ericsson's Solar Engine.

In many cases we want to know how much heat is brought from different portions of the solar spectrum. This is done by an apparatus of which a specimen is on exhibition here, invented by my friend Professor Langley, and called by him a bolometer.

This picture shows the apparatus of Professor Langley, by which he is enabled to show how much heat there is from the blue, from the yellow, and from the red part of the spectrum. The sensitive part consists of a sort of grid-iron of very thin strips of iron; the iron is from the ten thousandth to the twenty-five thousandth part of an inch thick, and each strip is about $\frac{1}{40}$ of an inch wide and about $\frac{1}{2}$ inch long. On each side is a similar grid-iron. Without going into the electrical details I will simply say that this sensitive grid-iron is placed in a tube, at this point here (pointing to figure) and is then connected with a galvanometer in such a way that if any heat falls upon it and so increases its electrical resistance above that of the two adjoining gratings, the spot of light will move upon the scale. With an apparatus of this kind you can deal with a spectrum of the light and examine the amount of heat in different portions of the spectrum. It is exquisitely sensitive; an amount of heat that would melt a pound of ice in five hundred years would be distinctly indicated.



Section of Bolometer Case and Bolometer.

The amount of heat given to the earth's surface by the sun is measured by the solar constant, it is twenty-five calories per square metre per minute, the calory being the amount of heat that will raise one kilogram of water one centigrade degree in temperature. Every square foot of the sun's surface is throwing off heat enough to be equivalent to about ten thousand horse-power. All the machinery at this exhibition could be run by one square foot of the sun's surface. I would not want a larger fortune than the control of one foot of the sun's surface; it would run a two thousand horse-power engine, year in and year out. The heat of the sun would thaw its way through a crust of ice about fifty feet thick in one minute of time, covering the whole surface of the sun. If I had a column of ice two and a quarter miles in diameter, and reaching the whole distance from here to the sun, and if I could by any means bring the whole solar heat to bear directly upon the ice, it would melt it within one second, and in seven seconds more would turn it into vapor.

This is probably a low estimate; Professor Langley has shown that this estimate of 25 calories will have to be increased, but he does not know whether it will have to be reckoned a little more or a little less than 30 to each square meter. The earth receives heat enough every year from the sun to melt a layer of ice a hundred feet thick all over the earth's surface if this heat were wholly expended upon ice-melting.

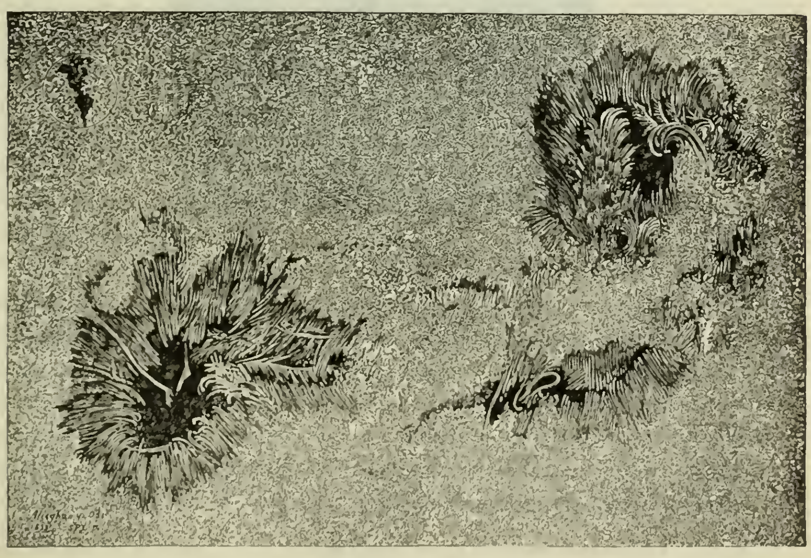
I now pass to the consideration of the sun's surface. One of the ways of studying that is by photograph. I show you upon the screen an instrument used at the last transit of Venus by a British party. It consists of a telescope with a camera box at the lower end. At this point is arranged an apparatus by which a slit in a plate of metal is made to flash across in front of the photographic plate on touching a trigger. That allows the sunlight for a moment to shine on the plate and make the picture.

Here is a picture taken by a similar instrument in 1869 at the time of the eclipse. I throw it on the screen, not so much to show the sun itself as to exhibit the contrast between the edges of the sun and the moon. The edge of the moon is very sharp and irregular. There are mountains on it a mile or two high; now the edge of the sun is very much more softened off. The edge of the moon is rocky, hard and flinty, but the edge of the sun is like wool or clouds. Here you see a sun spot and what is called a facula. You will also of course see a spider line across the picture to indicate east and west.

Here is a picture of the whole sun taken in 1872, by Rutherfurd of New York, in which you see many interesting points on the sun's surface. You will notice the darkening of the edge of the sun. As soon as you begin to make measurements of the brightness of the sun, you find that the centre is nearly four times as bright as the edge, and in the blue portion of the spectrum the difference is still greater. Those bright streaks are the so-called faculæ or "little torches" as the word means. At the time this was taken the spots were very large and numerous. They lie in two belts, and one of them is very marked on this picture. The axis of the sun lay in that direction; here is one of the zones of spots and the other is here. We shall of course see the characteristics of the spot better as we study them in detail. Here is a smaller picture magnified very much. The other plate was about the size it was originally taken; but this one is enlarged, some twenty or thirty times, as shown by this photograph. The sun's surface looks rough like drawing paper; it is not a smooth surface such as water would present, but it is in all probability a surface of clouds. You see here a dark ground-work scattered with brighter granules; at this point you see one spot nearly round, and here we have a group just breaking out with the penumbra partially formed, but not surrounding them symmetrically as yet.

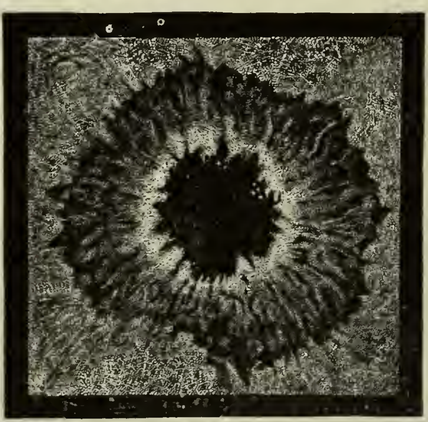
The photography of the sun has been carried further in France than in any other country. Here is one of Janssen's pictures. On that scale the sun would be about two hundred feet in diameter. You can see here the form and character of the granules on the solar surface. You will notice that in one place that the granules are nearly round; they look like finger tips turned towards you. In this corner on the other hand they are lying sideways toward you and appear much elongated. There is a spot in process of formation. Here is another place where the filaments are disturbed. Janssen found that if you take a pair of these pictures, at an interval of one minute, they would very nearly agree in all particulars, but if an hour or more should elapse between the pictures they would differ enormously; and remember that every one, even of these smallest granules, is two or three hundred miles in diameter. The surface of the sun seems to be made up of cloud-like masses floating in a gaseous atmosphere and I have no doubt that is the fact. Professor Langley compares the appearance of the surface of the sun to snow flakes on a gray overcoat, and an English physicist has said that it looks like pea soup.

Sometimes we wish to study the sun with the eye instead of by photograph. The photograph of course tells no lies, but it gives merely a brutal copy of what can be seen at any particular moment. With the eye you can look leisurely and can study what you see. The sunlight is so bright, however, that you must find some means of diminishing it. The apparatus now shown on the screen is the best for that purpose. It is known as a helioscope. The little thing is about five inches in diameter and five or six inches long. Here the sunlight enters; it is reflected at this first surface of glass, most of the light goes through the glass, but a little is reflected strike and this second surface; most of that light goes through again and the remainder is reflected. We first throw away nine-tenths of the light and then throw away nine-tenths of what is left. The remainder is reflected to another mirror of black glass; it is again reflected, and thus suffering four reflections before reaching the eye, each reflection at the angle of polarization. The upper box turns round upon the lower; when I turn one at right angles to the other I can cut the light entirely off, but when they are turned so that the mirrors are all parallel to each other the light is quite bright; so that by turning the upper box I have all the degrees of brightness. You thus see the solar surface with the greatest ease and comfort. We do not cut down the size of the lens, but let the whole light come through and then throw away what we do not want, saving enough for vision. I ought to say here that it is a mistake to cap the object glass of the telescope in order to diminish the light; sometimes you have to do it if you have not a proper eye-piece; but the definition is never so good on account of diffraction effects, and with such a helioscope as I have described, there is no difficulty in observing the sun with the whole 23 inches of aperture of our Princeton telescope.



Sun Spot of March 5, 1873, (after Langley.)

Here is a telescopic view with a lower power which shows another spot with the faculæ. The granules on the surface of the sun are shown nearly as well as by the photographs. Here is a picture by Professor Langley, the first of his pictures. I show it upon the screen because it gives you a more minutely accurate view of the solar surface than any other picture I know of. You notice this square in the corner, that is six thousand miles on a side, and the little markings in it are portraits. He very carefully depicted all the individual granules that appeared in these squares so that you get the actual shape and the size of what appeared at that time. The rest of the surface he made to agree in a general way with what you see in these squares. It takes a very large telescope not less than ten or twelve inches aperture, and under favorable circumstances to bring out distinctly what you see in this picture.



Spot of July 16, 1866. (Secchi.)

Here is a picture of a sun spot made at Berlin a year or two ago. When we come to examine a sun-spot we find that it has characteristic shapes at different ages. An old one is usually nearly round, but a new one like this is irregular. The central portion is dark, but not uniformly so. You will notice in the centre some dark holes (known as Dawe's holes) much darker than the rest, even of the umbra ; around it is what we call the penumbra.

(To be concluded.)

ON THE FRITTS SELENIUM CELLS AND BATTERIES.*

By C. E. Fritts.

In all previous cells, so far as I am aware, the two portions or parts of the selenium, at which the current enters and leaves it, have been in substantially the same electrical state or condition. Furthermore, the paths of the current and of the light have been transverse to each other, so that the two forces partially neutralize each other in their action upon the selenium. Lastly, the current flows through not only the surface layer which is acted upon the light, but also through the portion which is underneath and not affected thereby, and which therefore detracts from the actual effect of the light upon the selenium at the surface.

My form of cell is a radical departure from all previous methods of employing selenium, in all of these respects. In the first place, I form the selenium in very thin plates, and polarize them, so that the opposite faces have different electrical states or properties. This I do by melting it upon a plate of metal with which it will form a slight chemical combination, sufficient, at least, to cause the selenium to adhere and make a good electrical connection with it. The other surface of the selenium is not so united or combined, but is left in a free state, and a conductor is subsequently applied over it by simple contact or pressure.

During the process of melting and crystallizing, the selenium is compressed between the metal plate upon which it is melted and another plate of steel or other substance with which it will not combine. Thus, by the simultaneous application and action of heat, pressure, chemical affinity and crystallization, it is formed into a sheet of granular selenium, uniformly polarized throughout, and having its two surfaces in opposite phases as regards its molecular arrangement. The non-adherent plate being removed after the cell has become cool, I then cover that surface with a *transparent conductor of electricity*, which may be a thin film of gold leaf. Platinum, silver, or other suitable material may also be employed. The whole surface of the selenium is therefore covered with a good electrical conductor, yet is practically bare to the light, which passes through the conductor to the selenium underneath.* My standard size of cell has about two by two and a half inches of surface, with a thickness of $\frac{1}{1000}$ to $\frac{5}{1000}$ inch of selenium. But the cells can of course be made of any size or form. A great advantage of this arrangement consists in the fact that it enables one to apply the current and the light to the selenium in the same plane or general direction, instead of transversely to each other as heretofore done, so that I can cause the two influences to either coincide in direction and action or to act upon opposite faces of the selenium and oppose each other, according to the effect desired.

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* Paper read before the American Association for the Advancement of Science, at Philadelphia, Sept. 5, 1884.

By virtue of the process and arrangement described, my cells have a number of remarkable properties, among which are the following:

1. *Their Sensitiveness to Light* is much greater than ever before known. The most sensitive cell ever produced, previous to my investigations, was one made by Dr. Werner Siemens, which was 14·8 times as conductive in sunlight as in dark. In Table A, I give results obtained from a number of my cells.

TABLE A.—*Sensitiveness to Light.*

Selenium cell.	Battery power.	Resistance in dark.	Resistance in sunlight.	Ratio.
No. 22..............	5 elements	39,000 ohms	340 ohms	114· to 1
No. 23*.............	5 "	14,000 "	170 "	82·3 "
No. 24†.............	5 "	648,000 "	2,400 "	270· "
No. 25*....	5 "	180,000 "	930 "	196·5 "
No. 26*.............	5 "	135,000 "	710 "	190· "
No. 107..............	5 "	118,000 "	740 "	159· "
No. 108..............	5 "	200,000 "	900 "	222· "
No. 122..............	5 "	56,000 "	220 "	254·5 "
No. 129*.............	5 "	200,000 "	940 "	212· "
No. 137..............	5 "	108,000 "	320 "	337·5 "

* Cells No. 23 and No. 129 are now in possession of Prof. W. Grylls Adams, of Kings College, London; Dr. Werner Siemens has No. 25, and Prof. George F. Barker, of Philadelphia, has No. 26.

† No. 24 was measured with a bridge multiplier of 6 to 1.

It will be observed that I have produced one cell, which was 337·5 times as conductive in hazy sunlight as in dark. The tremendous change of resistance involved in the expression "337·5 times" may, perhaps, be more fully realized by saying that 99·704 *per cent.* of the resistance had disappeared temporarily, under the joint action of light and electricity, so that there remained *less than* $\frac{3}{10}$ *of 1 per cent. of* the original resistance of the selenium in dark.

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* The method of constructing the cells is described in the *Scientific American Supplement*, No. 462, for Nov. 8, 1884, translated from *La Lumiere Electrique.*

In order to obtain these maximum results, the cells must be protected from light when not in use. The resistance is first measured while the cell is still in total darkness. It is then exposed to sunlight, and again measured. It is also necessary to send the current in at the gold electrode or face, as the cell is much less sensitive to light when the light acts upon one surface of the selenium and the current enters at the opposite surface. When the two influences, the light and the current, act through the gold, in conjunction, their forces are united; and, as every atom of the selenium is affected by the light, owing to the extreme thinness of the plate, we have the full effect shown in the measurements.

Cells which are sensitive to light improve by being used daily, and their sensitiveness becomes less if they are laid aside and not used for a considerable length of time, especially if allowed to become overheated. They should be kept cool, and exposed to light frequently, whether they are used or not.

Mode of Measuring Cells.—So great is the sensitiveness of these cells to external influences, that it is necessary to adopt some particular system in measuring their resistance, and to adhere strictly to that system, as every change in the method of measurement produces a difference in the result, and the different measurements would not be comparable with each other. The reason for this will be explained presently.

The system I have adopted is the Wheatstone's bridge arrangement, with equal sides—never using multipliers in measurements for comparisons. In each multiplier wire I have 500 ohms resistance. When the bridge is balanced, one-half of the current flows through the cell and acts upon the selenium. Between the bridge and the cell is a reversing switch, so that the current can be reversed through the cell without changing its course through the bridge. A Bradley tangent galvanometer is used, employing the coil of 160 ohms resistance. The Leclanché battery is exclusively used in measurements for comparison.

2. *The Kind of Battery Employed* has a marked effect upon the sensitiveness to light, which is largely reduced or entirely destroyed when the bichromate battery is used. The same cells again become

extremely sensitive with the Leclanché battery. We might, perhaps, expect that a change in the current employed would cause a change in the *resistance* of a cell, but it is not clear how or why it should affect the *sensitiveness of selenium to light.*

"If one kind of battery current destroys its sensitiveness, may we not suppose that another kind might increase its sensitiveness? Although the Leclanché has operated well, some other may operate still better, and by its special fitness for use on selenium cells may intensify their actions, and so bring to light other properties yet unthought of. Is not here a promising field for experiment, in testing the various forms of battery already known, or even devising some new form especially adapted to the needs and peculiarities of selenium cells?"

One year ago I made the foregoing suggestions in a paper on "*A New Form of Selenium Cell*," presented before this Association at Minneapolis. I am now at liberty to state that my photo-electric battery, presently to be described, marks an advance in the direction indicated. The current from this battery increases the sensitiveness of the cells to light, and also to reversal of current. One cell whose highest ratio in light was about 83 to 1, with the Leclanché battery, when measured with my battery gave a ratio of 120 to 1. It seems to make the resistance of the cell both higher in dark and lower in sunlight than with the Leclanché battery. But the field is still open to others for the discovery of a battery which may be still better.

3. *The Two Surfaces of the Selenium Act Differently Towards Currents* sent into them from the contiguous conductors. One surface offers a higher resistance to the current than the other. The former I utilize as the anode surface, as I have found that the cell is more sensitive to light when the current enters at that surface, which is ordinarily the one covered by the gold or other transparent conductor. Some cells have this property but feebly developed, but in one instance the resistance offered to the current by the anode surface was 256 times as high as that offered by the cathode surface to the same current. In the majority of cases, however, the ratio does not exceed ten times. Table B gives some recent results, all measurements being made in the dark.

The direction of the current is always indicated by stating the position of the gold electrode, by the terms "gold anode," and "gold cathode."

Tarle B.—*Sensitiveness to Reversal of Direction of Current.*

No. of cell.	Battery.	Resistance, "gold anode."	Resistance, "gold cathode."	Ratio.
⅜ inch square, No. 4	5 elements	20,000 ohms	1,000 ohms	20· to 1
⅜ " " No. 3	*Se.* cell	6,500 "	400 "	16·2 "
Full size, No. 13	1 element	9,000 "	800 "	11·2 "
" No. 14	5 "	2,440 "	130 "	18· "
" No. 15	5 "	4,640 "	210 "	22· "
" No. 27	5 "	6,900 "	440 "	16· "
" No. 126	1 "	5,000 "	330 "	15· "

4. *Sensitiveness to Change of Battery Power.*—My cells are extremely sensitive to any change in the strength or character of the current flowing through them, which is shown by a corresponding change in the resistance of the cell. I can therefore vary the resistance of one of my cells in many ways, and the following may be specified:

(a.) By changing the potential or electromotive force of the current through the cell.

(b.) By changing the "quantity" of the battery or current.

(c.) By putting more or less resistance in the circuit.

(d.) By dividing the current by one or more branch circuits or shunts around the cell.

(e.) By varying the resistance in any or all of said circuits.

A cell whose resistance becomes greater as the battery power becomes greater, and *vice versa*, I call an "*L B* cell," signifying *Like the Battery power*. A "*U B* cell" is one whose resistance becomes greater as the battery power (or strength of current) becomes less, and *vice versa*, being *Unlike the Battery power*, or current strength.

These changes of resistance are not due to heating of the conductor or the selenium, and the following instance will illustrate this. I have one cell in which the selenium has about ¼ inch square of surface, melted on a brass block nearly one inch thick. This cell measured, with 25 elements of Leclanché, 40,009 ohms. On changing the battery to 5 elements, the resistance fell instantly to 30 ohms, and there remained. On again using the current from 25 elements, the resistance instantly returned to 40,000 ohms. Had these results been due in any degree to heating, the resistance would have changed gradually as the heat became communicated to the brass, whereas, no such change occurred, the resistances being absolutely steady. Moreover, even the fusion of the selenium would not produce any such change.

The "*U B*" property does not ordinarily change the resistance of the cell to exceed ten times, *i. e.*, the resistance with a weak current will not be over 10 times as high as with a strong one. But I have developed the "*L B*" property to a far higher degree. Table C gives some recent results obtained with *L B* cells, including one whose resistance, with 25 elements Leclanché, was 11,381 times as high as with 8 elements, and which, after standing steadily at 123 ohms (and then at 325 ohms with one element), on receiving the current from 25 elements again returned to its previous figure of 1,400,000 ohms.

TABLE C.—*Sensitiveness to Change of Battery Power.*

No. of Cell.			Resistance with 25 elements.	Resistance with 5 elements.	Ratio of Change.
⅜ inch square,		No. 1	40,000 ohms.	30 ohms.	1,333· to 1
⅜ "	"	No. 2	13,000 "	40 "	325· "
¼ "	"	No. 1	1,400,000 "	123* "	11,381· "
½ "	"	No. 2	500,000 "	62 "	8,064· "
½ "	"	No. 5	3,500 "	21 "	167· "
Full size,		No. 81	68,000 "	121 "	561· "
"	"	No. 82	9,000 "	64 "	140· "
"	"	No. 83	17,300 "	74 "	233· "
"	"	No. 119	35,600 "	19 "	1,894· "

* This measurement was obtained with eight elements.

The results in the table were obtained by changing the strength of current by throwing in more or less of the battery. Like results can be obtained by varying the current through the cell by any of the other methods before specified. All of the measurements were in the dark.

5. *Dual State of Selenium.*—My cells, when first made, seem to have two states or conditions. In one, their resistance is very low, in the other it is very high. When in the low state they are usually not very sensitive, in any respect. I therefore raise the resistance, by sending an intermittent or an alternating current through the cells, and in their new condition they at once become extremely sensitive to light,

currents and other influences. In some cases they drop to the low state again, and require to be again brought up, until, after a number of such treatments, they remain in the sensitive state. Occasionally a cell will persist in remaining in the insensitive state. The before-mentioned treatment raises it up for a moment, but, before the bridge can be balanced and the resistance measured, it again drops into the low or insensitive state. Some cells have been thus stimulated into the high or sensitive state repeatedly, and every means used to make them stay there, but without avail, and they have had to be laid aside as intractable.

In the earlier stages of my investigations, before the discovery of this dual state and of the method of changing a cell from the insensitive to the sensitive condition, hundreds of cells were made, finished, and tested, only to be then ruthlessly destroyed and melted over, under the impression that they were worthless. Now, I consider nothing worthless, but expect sooner or later to make every cell useful for one purpose or another.

The most singular part of this phenomenon is the wide difference in the resistance of the cells in the two states. In the low state it may be a few ohms, or even a few hundredths of an ohm. In the high state, it is the normal working resistance of the cell, usually between 5,000 and 200,000 ohms, but is often up among the millions. The spectacle of a little selenium being stimulated, by a few interruptions of the current through it, into changing its resistance from a fraction of an ohm up to a million or several millions of ohms, and repeatedly and instantly changing back and forth, up and down, through such a wide range—we might almost say, changing from zero to infinity, and the reverse, instantly—is one which suggests some very far-reaching inquiries to the electrician and the physicist. What is the nature of electrical conductivity or resistance, and how is it so greatly and so suddenly changed?

6. *Radio-electric Current Generators.*—My cells can be so treated that they will generate a current by simple exposure to light or heat. The light, for instance, passes through the gold and acts upon its junction with the selenium, developing an electromotive force which results in a current, proceeding from the metal back, through the external circuit, to the gold in front, thus forming a photo-electric dry couple or battery. It should preferably be protected from overheating, by an alum water cell or other well-known means.

The current thus produced is radiant energy converted into electrical energy directly and without chemical action, and flowing in the same direction as the original radiant energy, which thus continues its course, but through a new conducting medium suited to its present form. This current is continuous, constant, and of considerable electromotive force. A number of cells can be arranged in multiple arc or in series, like any other battery. The current appears instantly when the light is thrown upon the cell, and ceases instantly when the light is shut off. If the light is varied properly, by any suitable means, a telephonic or other corresponding current is produced, which can be utilized by any suitable apparatus, thus requiring no battery but the selenium cell itself. The strength of the current varies with the amount of light on the cell, and with the extent of the surface which is lighted. I produce current not only by exposure to sunlight, but also to dim diffused daylight, to moonlight, and even to lamplight. I use this current for actual working purposes; among others, for measuring the resistance of other selenium cells, with the usual Wheatstone's bridge arrangement, etc., before described. I have also used it for signaling, for telephonic and similar purposes. Its use for photometric purposes, and in current-regulators will be mentioned further on. It is undoubtedly available for all uses for which other battery currents are employed, and I regard it as the most constant, convenient, lasting, readily used and easily managed pile or battery of which I have any knowledge. On the commercial scale, it could be produced very cheaply, and its use is attended by no expense, inasmuch as no liquids or chemicals are used, the whole cell being of solid metal, with a glass in front, for protection against moisture and dust. It can be transported or carried around as easily and safely as an electro-magnet, and as easily connected in a circuit for use wherever required. The current, if not wanted immediately, can either be "stored" where produced, in storage batteries of improved construction devised by me, or transmitted over suitable conductors to a distance, and there used, or stored as usual till required.

7. *Singing and Speaking Cells.*—When a current of electricity flowing through one of my selenium cells is rapidly interrupted, a sound is given out by the cell, and that sound is the tone having the same number of air variations per second as the number of interruptions in the current. The strength of the sound appears to be independent of the direction of the current through the cell. It is produced on the face of the cell, no sound being audible from the back of the cell. An

alternating current also produces a sound corresponding to the number of changes of direction. Experiments also show that, if a telephonically undulating current is passed through the cell, it will give out the speech or other sound corresponding to the undulations of the current, and furthermore, that the cell will sing or speak in like manner without the use of a current, if a suitably varied light is thrown upon it while in closed circuit.

My experiments having been devoted especially to those branches of the subject which promised to be more immediately practically valuable, I have not pursued this inquiry very far, and offer it for your consideration as being not only interesting, but possibly worthy of full investigation.

General Observations on the Properties of Cells.—From the number of different properties possessed by my cells, it might be anticipated that the different combinations of those properties would result in cells having every variety of action. This is found to be the case. As a general rule, the cells are noteworthy in one respect only. Thus, if a cell is extremely sensitive to light, it may not be specially remarkable in other respects. As a matter of fact, however, the cells most sensitive to light are also "*U B* cells."

The property of sensitiveness to light is independent of the power to generate current by exposure to light—the best current-generating cells being only very moderately sensitive to light, and some of the most sensitive cells generate scarcely any current at all. Current-generating cells are, almost without exception, "*U B* cells," and the best current-generating cells are strongly polarized, showing a considerable change of resistance by reversing the direction of a current through them ; and they are also strong "anode cells," *i.e.*, the surface next to the gold offers a higher resistance to a battery current than the other surface of the selenium does. The power to generate a current is temporarily weakened by sending a battery current through the cell while exposed to light, in either direction. The current generated by exposure to light is also weakened by warming the cell, unless the cell is arranged for producing current by exposure to heat.

The properties of sensitiveness to light and to change of battery power are independent of each other, as I have cells which are sensitive to change of current but absolutely insensitive to light, their resistance remaining exactly the same whether the cells are in darkness or in sunlight. I also have cells which are sensitive to light, but are unaffected by change of battery power or by reversing the direction of the current through them.

The sensitiveness to change of battery power is also independent of the sensitiveness to reversal of direction of the current. Among the best "*L B* cells" some are "anode cells" and others are "cathode cells," while still others are absolutely insensitive to reversal of current or to the action of light.

Constancy of the Resistance.—A noticeable point in my cells is the remarkable constancy of the resistance in sunlight. Allowing for difference in the temperature, the currents, and the light, at different times, the resistance of a cell in sunlight will remain practically constant during months of use and experiments, although during that time the treatments received may have varied the resistance in dark hundreds of thousands of ohms—sometimes carrying it up and at others carrying it down again, perhaps scores of times—until it is "matured," or reaches the condition in which its resistance becomes constant.

As has already been stated, the sensitiveness of a cell to light is increased by proper usage. This increased sensitiveness is shown, not by a lowered resistance in light, but by an increased resistance in dark. This change in the cell goes on, more or less rapidly, according as it is retarded or favored by the treatment it receives, until a maximum is reached, after which the resistance remains practically constant in both light and dark, and the cell is then "matured" or finished. The resistance in dark may now be 50 or even 100 times as high as when the cell was first made, yet whenever exposed to sunlight it promptly shows the same resistance that it did in the beginning. The various treatments, and even accidents, through which it has passed in the meantime, seem not to have stirred its molecular arrangement under the action of light, but to have expended their forces in modifying the positions which the molecules must normally assume in darkness.

Practical Applications.—There are many peculiarities of action occasionally found, and the causes of such actions are not always discernible. In practice I have been accustomed to find the peculiarities and weaknesses of each cell by trial, developing its strongest properties and avoiding its weaknesses, until, when the cell is finished, it has a definite and known character, and is fitted for certain uses and a certain line of treatment, which should not be departed from, as it will be at the risk of temporarily disabling it. In consequence of the time and labor expended in making cells in the small way, testing, repairing damages done during experiments, etc., the cost of the cells now is unavoidably rather high. But if made in a commercial way, all this would be reduced to a system, and the cost would be small. I may say here that I do not make cells for sale.

The applications or uses for these cells are almost innumerable, embracing every branch of electrical science, especially telegraphy, telephony and electric lighting, but I refrain from naming them. I may be permitted, however, to lay before you two applications, because they are of such general scientific interest. The first is my

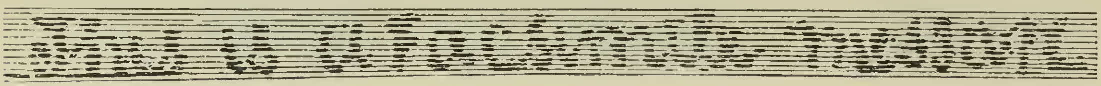
Photometer.—The light to be measured is caused to shine upon a photo-electric current-generating cell, and the current thus produced flows through a galvanometric coil in circuit, whose index indicates upon its scale the intensity of the light. The scale may be calibrated by means of standard candles, and the deflections of the index will then give absolute readings showing the candle.power of the light being tested. Or, the current produced by that light and that produced by the standard candle may be compared, according to any of the known ways of arranging and comparing different lights—the cell being lastly exposed alternately to the two lights, to see if the index gives exactly the same deflection with each light.

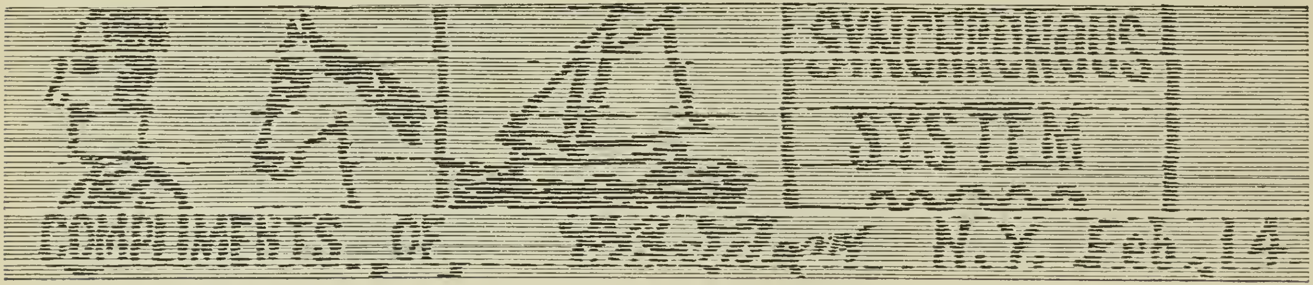
This arrangement leaves untouched the old difficulty in photometry, that arising from the different *colors* of different lights. I propose to obviate that difficulty in the following manner: As is well known, gold transmits the green rays, silver the blue rays, and so on; therefore, a cell faced with gold will be acted upon by the green rays, one faced with silver by the blue rays, etc. Now if we construct three cells (or any other number) so faced that the three, collectively, will be acted upon by all the colors, and arrange them around the light to be tested, at equal distances therefrom, each cell will produce a current corresponding to the colored rays suited to it, and all together will produce a current corresponding to all the rays emitted by the light, no matter what the proportions of the different colors may be. The three currents may act upon the same index, but each should have its own coil, not only for the sake of being able to join or to isolate their influences upon the index, but also to avoid the resistances of the other cells. If a solid transparent conductor of electricity could be found which could be thick enough for practical use and yet would transmit all the rays perfectly, *i. e.*, transmit white light unchanged, that would be still better. I have not yet found a satisfactory conductor of that kind, but I think the plan stated will answer the same purpose. This portion of my system I have not practically tested, but it appears to me to give good promise of removing the color stumbling-block which has so long defied all efforts to remove it, and I therefore offer it for your consideration.

Photo-electric Regulator.—My regulator consists of a current-generating cell arranged in front of a light, say, an electric lamp whose light represents the varying strength of the current which supports it. The current produced in the cell by this light flows through an electromagnetic apparatus by means of which mechanical movement is produced, and this motion is utilized for changing resistances, actuating a valve, rotating brushes, moving switches, levers, or other devices. This has been constructed on a small scale and operates well, and I think it is destined to be largely used, as a most sensitive, simple and perfect regulator for currents, lights, dynamos, motors, etc., whether large or small.

In conclusion, I would say that the investigation of the physical properties of selenium still offers a rare opportunity for making very important discoveries. But candor compels me to add that whoever undertakes the work will find it neither an easy nor a short one. My own experience would enable me to describe to you scores of curious and suggestive results, but lack of time prevents my giving more than this very incomplete outline of my discoveries.

PRESENT CONDITION OF KRAKATOA.—Messieurs Brêhn and Korthals have recently visited Krakatoa and given an account of the volcanic action. At some distance from the island, clouds of vapors seemed to hover over the crater, which suggested the existence of fumeroles; but on approaching with a canoe, they found that what they had taken for a vapor was nothing but dust, produced by a continual bombarding of projectiles of every magnitude, which fell from the summit. There are numerous layers of rocks, separated by small beds of sandy tufa, which are so common in all volcanic countries. The rocks appeared to belong to the family of basalts. The present eruption was accompanied by very acid pumice, containing 72 per cent. of silex, with plagioclase, bronzite and magnetite. The original material, which by its gaseous emulson produced the pumice, is a bottle-green glass, bits of which are found in the pumice beds.—*Comptes Rendus*, Aug. 25, 1884. C.




SYNCHRONOUS
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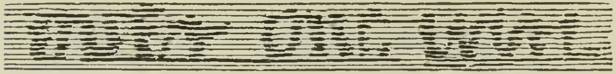


DELANY'S FAC-SIMILE TELEGRAPHIC TRANSMISSION.

By Prof. Edwin J. Houston.

It will doubtless interest the readers of the Journal to learn that Mr. P. B. Delany, the inventor of the first successful synchronous-multiplex telegraphic system, has fulfilled the promise he made a long time ago, and has practically applied his invention to fac-simile transmission, whereby the hand-writing of a correspondent, pen sketches, maps, plans, hieroglyphics, etc., can be sent over a telegraph wire and reproduced at the receiving station with all their distinctive characteristics.

I have had occasion, in previous articles on the synchronous-multiplex system, to call attention to the fact that the synchronous division of an ordinary telegraph wire into a number of parts, would eventually be applied to the transmission of fac-simile despatches. I have to-day received from Mr. Delany copies of the first fac-simile transmission with a crude experimental apparatus, which is herewith reproduced.

Although other systems of fac-simile transmission have been tried, and fac-simile dispatches have been sent and successfully reproduced, yet when but a single wire was employed, the time required for the transmission was so protracted, and the uncertainty of correct reproduction so great, that such systems of transmission could never come into actual commercial use.

Mr. Delany's system, however, differs from the preceding in that it insures speed and certainty of correct reproduction. By means of the application of his synchronous system an area of twelve square inches can be covered in one minute by the use of a single wire.

The many uses of this system of fac-simile transmission can scarcely be properly appreciated at this time; for, notwithstanding the comparatively coarse lines that are so evident in the specimens annexed, yet with more carefully prepared apparatus, constructed for actual use, we do not doubt but that Mr. Delany will be able to transmit portraits, and other similar work equal in fineness to the ordinary wood-cut, so that criminals may be readily intercepted in their flight by the telegraphing of their portraits; or, in times of war, maps showing the movements of armies, sketches of fortifications and works may be transmitted; or the illustrated papers may be furnished, telegraphically, with sketches of disasters, at the same time that particulars of the same are being transmitted to them.

An evident advantage of such a system of telegraphic transmission is in the readiness with which it can telegraph in any language, even Chinese, for instance.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, February 20, 1885.

CORRESPONDENCE.

AN INTERESTING AND SATISFACTORY EXPERIMENT. — PUMPING MOLASSES.—The Grocers' Sugar House (proprietor George E. Bartol), situated on Passyunk road near Washington avenue, at a distance of 6,600 feet from its wharf, foot of Reed street, on the Delaware, requires in its business 130 hogsheads, or 17,500 gallons of imported molasses daily. Heretofore it has been hauled by trucks at considerable expense as well as much injury to street pavements. The great success in pumping oil long distances determined Mr. B. to make the trial on molasses, although the article to be pumped was very different in character.

He decided to lay a three-inch wrought iron pipe which, in the distance named, has an elevation of twenty-three feet and makes five right-angle bends. The operation is as follows: the hogsheads of molasses are emptied at the wharf into a large iron tank, connected with which is a Blake steam pump, having a steam cylinder of fourteen inches diameter and a pump of five inches diameter, both twelve inches stroke. This pump discharges into the three-inch wrought iron pipe before mentioned. The density of the molasses varies with the temperature of the atmosphere, and at times it is necessary to heat it to a temperature of 110 degrees, and in some cases a little water has to be added. The pressure on the pump is not allowed to go beyond 400 lbs. to the square inch, and it is rarely that it reaches that, and it does not go below 250 lbs. The average daily work—of 17,500 gallons, as before stated—requires twenty-two double strokes of the pump per minute, delivering 2,000 gallons per hour; the difference between the capacity of the pump at that velocity and the amount of molasses actually delivered is ·10 per cent., showing that, owing to the density of the molasses, the pump does not fill to its full capacity.

After being in operation 18 weeks, it is demonstrated that all of the molasses emptied at Reed street wharf is delivered at the sugar house, also that no injury is done to the molasses by being pumped that distance under pressure. The pipe was laid and pump erected under the immediate supervision of Mr. Rafael Estrada, an experienced engineer, who is superintendent of the sugar house. B. H. B.

Committee on Publication of Franklin Institute, Philadelphia:

GENTLEMEN:—In the JOURNAL OF THE FRANKLIN INSTITUTE for December last, appeared a reprint from *Mechanics* for November, of an article by Mr. C. E. Simonds, of East Cambridge, Mass., on the subject of standard dimensions for the heads and nuts of bolts. This extract was followed by a reply from Mr. Coleman Sellers.

Mr. Simonds, in the course of his remarks, alludes, with some dissatisfaction, to the remarks on this subject given in a recent edition of "Trautwine's Civil Engineer's Pocket Book," and I, therefore, take occasion to say that some months ago I rewrote the remarks on this subject for the forthcoming edition, putting them, as I believe, in accordance with the present state of the case.

The amended article reads as follows:

BOLTS, NUTS AND WASHERS.—The following dimensions for bolts and nuts were proposed by Mr. Wm. Sellers and adopted by the Franklin Institute, of Phila., as a standard, in 1864, and by the U. S. Navy Dept.,* in 1868. They have been adopted by the principal machinists of the country, and are known as "Franklin Institute Standard" or "Sellers" dimensions. The angle a, Fig. 1, between the two sides of a thread, is 60°. w is the width (measured lengthwise of the bolt) of the flat top and bottom of each thread. N is the number of threads per inch of length of screw.

D In.	d In.	w In.	N
¼	·185	·0062	20
$\frac{5}{16}$	·210	·0074	18
⅜	·294	·0078	16
$\frac{7}{16}$	·344	·0089	14
½	·400	·0096	13
$\frac{9}{16}$	·454	·0104	12
⅝	·507	·0113	11
¾	·620	·0125	10
⅞	·731	·0138	9
1	·837	·0156	8
1⅛	·940	·0178	7
1¼	1·065	·0178	7
1⅜	1·160	·0208	6
1½	1·284	·0208	6
1⅝	1·389	·0227	5½
1¾	1·491	·0250	5
1⅞	1·616	·0250	5
2	1·712	·0277	4½
2¼	1·962	·0277	4½
2½	2·176	·0312	4
2¾	2·426	·0312	4
3	2·629	·0357	3½
3¼	2·879	·0357	3½
3½	3·100	·0384	3¼
3¾	3·317	·0413	3
4	3·567	·0413	3
4¼	3·798	·0435	2⅞
4½	4·028	·0454	2¾
4¾	4·256	·0476	2⅝
5	4·480	·0500	2½
5¼	4·730	·0500	2½
5½	4·953	·0526	2⅜
5¾	5·203	·0526	2⅜
6	5·423	·0555	2¼

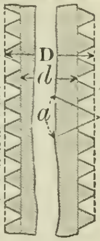
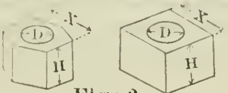


Fig.1

Rough heads and nuts. $X = 1\frac{1}{2}D + \frac{1}{8}$ inch. H (in *head*) = $\frac{1}{2}X$. H (in *nut*) = D. Finished heads and nuts. $X = 1\frac{1}{2}D + \frac{1}{16}$ inch. H (in *head*) = H (in *nut*) = $D - \frac{1}{16}$ inch. In the "Whitworth" (English) standard thread, the angle a, Fig. 1, is 55°. The tops and bottoms of the threads are rounded, instead of flat, as in the American standards. The number (N) of threads per inch is the same as above for diameters of bolt up to 3 in., except for D = ½ inch, where N = 12.



Figs.2

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* Except that the Navy Department uses, *for both rough and finished heads and nuts*, the dimensions given above for *rough* heads and nuts. The standard of the Navy Department is known as "United States Standard."

Yours very respectfully,

JOHN C. TRAUTWINE, JR.

PHILADELPHIA, *January* 23, 1885.

SOLAR PHENOMENA IN SWITZERLAND.—The reddish limb, by which the sun was often surrounded during the past summer, was very brilliant among the high Alps, and often approached a silvery whiteness near the sun, into which orange or violet tints were blended from a large exterior reddish corona, the limits of which were ill-defined. Beyond the corona, for a considerable distance, the sky was of a much darker blue than usual. —*Comptes Rendus*, Aug. 11, 1885. C.

Book Notices.

THE MODERN HIGH EXPLOSIVE. By Manuel Eissler. New York: John Wiley & Sons. 8vo, pp. xi + 388.

This book is a descriptive history of "nitroglycerin and dynamite, their manufacture, their use, and their application to mining and military engineering; pyroxylin, or gun-cotton; the fulminates, picrates and chlorates, also the chemistry and analysis of the elementary bodies which enter into the manufacture of the principal nitro-compounds." It is a satisfactory and interesting work as regards the treatment of the application of explosion to engineering operations, and at the same time an unscientific and faulty compilation of the chemistry of the subject. Especially is to be condemned the indiscriminate use of nearly all possible synonyms used in the chemical nomenclature of explosive compounds. These inequalities are probably to be attributed to the fact that the subject is treated from an engineer's standpoint.

A large portion of the book is made up of *literatim* quotations, properly credited, from the works of Abel, Drinker, Berthelot and Mowbray.

Apart from its somewhat questionable scientific value, this treatise will prove interesting and useful in its information of the extended and varied uses to which dynamite and nitroglycerin are now habitually applied. Some of the statements are really surprising: "At Smartsville, in California, it is almost a daily occurrence to fire blasts where twenty thousand, thirty thousand, and even fifty thousand pounds of explosives are burnt in one charge." Limestone quarries are mentioned where twenty thousand pounds are fired at one blast. The description of the applications of exploplosives to agriculture, tunnel-driving, channel deepening, pile-driving, etc., are no less entertaining, and will well repay a perusal of Parts II and III of the book, which is clearly printed on good paper.

A TREATISE ON ORE DEPOSITS. By J. Arthur Phillips, F.R.S., V.P.G.S., M. I. C. E., etc. With numerous illustrations. London: Macmillan & Co., 1884. For sale by J. B. Lippincott & Co., Phila.

This book may be said to give among the first visible signs of the change in the direction of English scientific method in matters relating to applied geology and mineralogy, which has nevertheless been apparent for some years to those whose studies brought them much in contact with the outer British pickets (so to speak) on these lines of investigation. For many years England monopolized the leadership in all applications of science to the arts; and in no cases more markedly than in metallurgy and mining.

This was not because other nations had not made great progress in these arts, but partly on account of the greater difficulties of an interchange of experiences of the more important manufacturers in different countries. What would once have been thought an accomplishment of a high order, viz.: the ability to read one or more foreign tongues with facility, is now expected of every beginner; and, more than this, the ability and desire to profit by the results of one's foreign rivals are almost universal. This is as true of science as of trade. So that in spite of the indifference with which English scientific men professed to regard the improvements in the methods of attacking mining problems by building up the science of petrography (an improvement almost wholly due to the Germans) the advanced minds in England have not only accepted the new method but also improved it. This is apparent in the work before us on every page, and, indeed, in the first line of the preface, where the author pays a graceful tribute to the distinguished von Cotta and by inference to his American translator, Mr. Prime. The willingness of Englishmen to acknowledge merit in works published in America is not so venerable a characteristic as to be, of itself, entirely devoid of significance.

The book is divided into a general and a special part; the first treating of ore deposits in the abstract and containing much matter, both as illustration and as text, which has never before been printed, and which is admirable.

This material is taken as well from foreign as from English sources, and shows both familiarity with the literature and good judgment in the selection of examples.

The second part deals with the actual ore deposits of the different countries of the world beginning, of course, with England.

The first part takes 106 pages, followed by two very valuable pages of general conclusions. In these latter it is noteworthy to find an Englishman so far severing himself from the traditions of his countrymen as to acknowledge (p. 106) that there is no sharp division possible between "bed-veins" and "fissure-veins."

The mining world has been so long held in thrall by this kind of hair-splitting, that it is a great relief to find it ignored in an English work of authority. A previous part of the book, viz.: the discussion of the influence of the country rock upon veins, deserves even higher praise, and is a contribution of permanent value to the literature of economic geology.

The subject is first considered statistically, and then under the head of the "Genesis of Mineral Veins," a bibliographical notice of the opinions held up to the time of (and including) Werner, leads to the categorical discussion of all the modern theories which our author deems worthy of mention. These are seven, viz.: 1, Contemporaneous Injection; 2, Igneous Injection; 3, Electric Currents; 4, Aqueous Deposition from above; 5, Sublimation; 6, Lateral Secretion; 7, Ascension. The importance of 6 is well brought out in its fuller treatment; and the contributions of Sandberger and Forschammer are fairly acknowledged.

In this part, too, we notice several sketches from nature by that excellent observer, Clement LeNeve Foster, H. M. Inspector of Mines in Wales. In the second part, Cornwall, of course, claims the first as well as the largest part of the description of England's mining districts, in fact more than the third of all those of the United Kingdom combined. France is finished in 18 pages, while Cornwall required 38; but this is less the result of national prejudice than a desire to avoid repeating what has already been used for the purposes of illustration in the citation of English localities, which, as a general rule, are more instructive. Belgium claims 2 pages; the German Empire but 52; Austria-Hungary, 22; Italy, 12; Greece, 8; Spain, 10; Portugal, 4; Scandinavia, 12, and Russia, 10.

The Indian Empire occupies 25 pages; the Australasian colonies, 65; Africa must get along with 4 pages; while the Land of Freedom is complimented by having 57 pages dedicated to its mining affairs (more, even than Cornwall), and Canada receives 25 pages. All South America is comfortably stowed away in 9 pages.

The book will be almost a necessity to every instructor in the branches with which it deals, while it will be indispensable to the field geologist and mining engineer who has the ambition to keep abreast of the progress in his profession. P. F.

THE STEAM ENGINE INDICATOR AND ITS USE.—By W. B. Le Van. Van Nostrand's Science Series.

Judging this little book in its relation to the numerous class aspiring to become familiar with the Steam Engine Indicator, its usefulness is undeniable; for it contains all the information which can be given to this class, composed principally of men to be found in the workshop and in the engine-room.

The author has premised wisely a number of popular historical notions bearing on the mechanical equivalent of heat, and properties of steam, which, although not absolutely necessary for the understanding of the subject, are well designed to elevate the working mechanic, and to inspire him with respect and gratitude for those who have devoted, and for those who are devoting, their lives to the cause of science. L. d'A.

INFLUENCE OF LIGHT ON TISSUES WITHOUT CHLOROPHYLL.—G. Bonnier and L. Mangin, in their physiological studies of mushrooms, investigated the influence of light upon respiration. A new series of experiments upon the respiration of tissues without chlorophyll, has led them to the following conclusions:

I. Solar light, direct or diffused, other conditions being equal, attenuates more or less the intensity of respiration.

II. For the same individuals, the ratio of the volume of carbonic acid emitted to the volume of oxygen absorbed is the same in light and in darkness.—*Comptes Rendus*, July 21, 1884. C.

INFLUENCE OF INTELLECTUAL WORK ON THE ELIMINATION OF PHOSPHORIC ACID.—A. Mairet has made numerous observations upon the modifications which are produced by intellectual labor in the elimination of phosphoric acid, and formulates the following conclusions: 1. Phosphoric acid is intimately connected with nutrition and with the activity of the brain. The brain, when acting, absorbs carbonic acid united with alkalies, and gives out phosphoric acid united with earths. 2. Intellectual labor slackens the general nutrition. 3. In the excretions, intellectual labor diminishes the amount of phosphoric acid which is united with alkalies and diminishes the amount which is united to the earths.—*Comptes Rendus*, Aug. 11, 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, February* 18, 1885.]

HALL OF THE INSTITUTE, February 18, 1885.

MR. WILLIAM P. TATHAM, President, in the Chair.

Present, 103 members, and 3 visitors.

Five persons were reported as having been elected members at the last meeting of the Board.

The unanimous election of MR. HERBERT L. HEYL, as Actuary, in place of Mr. D. S. Holman, who declined a re-election, was reported by the Secretary.

Mr. Barnet Le Van read the paper of the evening on "The Economy in the Use of High-Pressure Steam." The paper was discussed by Messrs. Orr, Bilgram and the author, and, together with the discussion, has been referred to the Committee on Publication.

The Secretary's report embraced comments on the World's Fair at New Orleans; the last annual report of the Commissioner of Patents; the failure of the Nicaragua Treaty and its influence on the projected canal across that portion of the Isthmus; the recent disasters from the explosion of natural gas in Pittsburgh, and the necessity of taking stringent measures to provide against them; and the description of several interesting novelties. Among these there was shown on the screen and described, a projected tower 100 meters high, which it is proposed to erect in Paris, in connection with the Universal Exposition of 1889, which it is proposed to hold in that city. The design of this tower is by M. G. Eiffel, and its details are described in the *Annales des Travaux Publics*, November, 1884. A view of a new rotary stone-cutting machine, having some novel features was shown. The machine has a circular cutting-disk furnished with insertable teeth; the disk is driven from the *periphery*, being simply journaled loosely on the axle; is fed slowly; and makes its cut backwards and upwards. This machine is the invention of Messrs. John H. Crump and Richard Brereton, of Philadelphia, and is found specially serviceable for quarrying slate. A detailed description of this machine has been referred for publication.

The Secretary described, on behalf of Mr. Russell Thayer, C. E., of Philadelphia, a plan of avoiding the explosion of oil tanks from lightning, by "introducing steam into the tank between the roof of the same and the surface of the oil." The theory of the author is that such explosions are caused by concussion, and that if the gases generated from the oil are saturated with water vapor, such mixture of gas and water vapor is not explosible by concussion or otherwise.

There were also shown, on behalf of Messrs. Jas. W. Queen & Co., several analytical balances of improved construction, and of great delicacy and accuracy; and a miner's safety-lamp, embodying several substantial improvements.

A new method of producing manifold copies of writing was shown and described. It is called the "Cyclostyle," and permits of the reproduction of several thousand permanent impressions in black ink.

The process is briefly as follows: A sheet of oiled, or tracing, paper is fixed in a rectangular frame, the bed of which is a smooth surface of metal. The circular or other matter is then written on this sheet of paper with the cylostyle pen. This consists of an ordinary wooden holder, at the end of which is a small spindle at right angles with the holder, on which spindle is pivoted a minute circular disk of platinum, with a sharp milled edge. This wheel revolves in the direction of the writing and cuts a stencil in the oiled paper. The copies produced closely resemble ordinary writing, the minute dots appearing to the unaided eye as a continuous line.

Immediately after the writing is finished, the printing may, if desired, be commenced. Any paper may be used for printing, though unglazed paper is preferred for the reason that it dries more rapidly than one that is highly glazed. The printing is done by laying the sheet to be printed on the metal bed, placing the stencil down over it and passing an inking roller over the face of the stencil. The stencil is then raised, the printed impression removed, a fresh blank sheet substituted, and the operation is repeated.

Any error can be rectified by simply rubbing the stencil with the thumb nail, when the holes will be found to close and any other word or words can then be written in substitution. The original may be left for any length of time, and further copies taken when required. Copies can be obtained at the rate of several hundred per hour, and it is said that as many as 2,000 copies can be made from a single stencil.

The President named the following standing committees for the year:

Library.—Charles Bullock, J. Howard Gibson, Frederick Graff, Wm. D. Marks, S. H. Needles, Isaac Norris, Jr., A. E. Outerbridge, Jr., T. D. Rand, Charles E. Ronaldson, Lewis S. Ware.

Minerals.—Clarence S. Bement, Persifor Frazer, F. A. Genth, Edwin J. Houston, George A. Koenig, Otto Lüthy, E. F. Moody, H. Pemberton, Jr., Theo. D. Rand, Wm. H. Wahl.

Models.—Edward Brown, H. L. Butler, C. Chabot, L. L. Cheney, N. H. Edgerton, John Goehring, Morris L. Orum, Chas. J. Shain, John J. Weaver, S. Lloyd Wiegand.

Arts and Manufactures.—J. Sellers Bancroft, George Burnham. Cyrus Chambers, Jr., George V. Cresson, Wm. Helme, Wm. B. Le Van, Alfred Mellor, J. W. Nystrom, Henry Pemberton, John J. Weaver.

Meteorology.—David Brooks, J. B. Burleigh, William A. Cheyney, J. A. Kirkpatrick, F. B. Maury, Isaac Norris, Jr., Hector Orr, Alex. Purves, Wm. H. Wahl.

Meetings.—Chas. H. Banes, Hugo Bilgram, A. B. Burk, G. M. Eldridge, Fred'k Graff, Henry R. Heyl, Washington Jones, H. Pemberton, Jr., E. Alex. Scott, Coleman Sellers.

After the transaction of some formal business, the meeting was adjourned.

WM. H. WAHL, *Secretary.*

LIST OF BOOKS

ADDED TO THE LIBRARY FROM JULY, 1884, TO JANUARY, 1885.

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JOURNAL

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VOL. CXIX. APRIL, 1885. No. 4

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ON THE MODIFICATIONS OF TENSILE STRENGTH AND DUCTILITY WHICH IRON AND STEEL UNDERGO WHEN HEATED TO BETWEEN CERTAIN TEMPERATURES.

[Translation by Chief Engineer Isherwood, United States Navy, of the paper on that subject read by Engineer-in-Chief E. Cornut of the North of France Association, before the 7th Congress of the Engineers-in-Chief of the Associations of Proprietors of Steam Boilers, held at Bordeaux, France, on the 10th, 11th and 12th September, 1882.]

[NOTE BY TRANSLATOR.—The influence of temperature on the ductility, elasticity, and cohesive strength of wrought-iron and of steel, though of great importance in the industrial arts, has received so little attention, owing doubtless to the difficulty and cost of the investigation, that any new experimental facts on the subject have exceptional value, particularly as plate steel in the various modifications of iron which bear that name, is coming into general use for boilers, and for the hulls of vessels, I have therefore translated the following paper read by Mr. Cornut, the distinguished Engineer-in-Chief of "The North of France Association," before the 7th Congress of the Engineers-in-Chief of "The Associations of the Proprietors of Steam Boilers," held at Bordeaux, France, on the 10th, 11th and 12th of September, 1882, which contains some valuable facts and inferences concerning this subject.

In the paper referred to, is given the true explanation of the apparently abnormal result that iron and steel increase in cohesive strength by increase of temperature up to about 550 degrees Fahrenheit, instead of diminishing, as do all other substances. The rupturing strain, it is important to observe, being referred to the original cross section of the specimen tested and not to the cross section at the instant of fracture. That such is the effect has long been known, but not the cause producing it, namely, the great loss of ductility experienced by iron and steel when heated between certain temperatures, whereby the section of fracture of a bar of given dimensions is larger at these temperatures than at lower ones. Hence, the imaginary increase of strength due to the increase of temperature is not a physical fact but an erroneous inference resulting from an unwarranted implied assumption that the sections of fracture at different temperatures have the same proportion to the original section. As the metal loses in ductility it necessarily gains in brittleness, so that increase of the latter is proof of decrease of the former.

Had the section of fracture been measured in the few experiments on the cohesive strength of heated iron and steel which have been made, and had the rupturing force been referred to it and not to the section before the strain was applied, and had the heated metal been tested at the same time for brittleness by bending it, the cause of the *apparent* increase of strength due to increase of temperature would have been revealed, and it would have been found that iron and steel instead of being exceptions to the general law of decreased strength with increased temperature, obeyed that law.

Very important, too, in engineering, is a knowledge of the facts that the increase of temperature referred to, increases the brittleness of iron and steel, and of steel more than of iron, as it accounts for many fractures, impossible to otherwise explain, of marine engine shafts. Perhaps most of these fractures—particularly of crankshafts—are due to the overheating of the journals, which is sometimes great enough to fuse the brass of their bearings. It is well known that crankshafts, both iron and steel, the journals of which are liable to become highly heated as the pressure under which they work is often very great per square inch of surface, fracture much more frequently than their corresponding line shafts, although the latter are generally of less diameter. Steel shafts are much more subject to these accidents than iron ones, and at high temperatures the brittleness of steel due to temperature is greater than that of iron. For this reason, externally fired cylindrical boilers constructed with steel shells would, when overheated, be more liable to rupture than if constructed with iron shells.

In this connection I may remark that the high tensile strength shown by small specimens of the plate steel now coming into use for boilers and for the hulls of vessels, cannot be accepted for the plates from which they were cut as a whole. Owing to the mode of manufacture and the nature of the material, the metal of these plates is under permanent violent abnormal internal strains, and the larger the plates, the greater are these latent dangerous strains, but when a small piece is cut from them, it is relieved from these strains and being then tested shows a tensile strength much exceeding what belongs to the plate as a whole.

The existence of these abnormal strains is proven by the sometimes spontaneous fracture of the plates while lying in store, or when roughly handled or when slightly struck. They can be lessened in measure by annealing the plates, but annealing effects a very serious reduction in their strength. Plate iron is free from these strains, and though greatly less homogeneous in structure than the steel in question, is more uniform and reliable in its qualities of tensile strength, of ductility at all temperatures, and of resistance to corrosion.

In this connection the reader's attention is particularly called to the illustration accompanying Mr. Walrand's very acute experiments described by Mr. Cornut.

It is hoped that the Navy Department, which is the great user of steel for boilers and for hulls of vessels in the United States, will have extensive experiments made by means of the large testing machine at Watertown, Massachusetts, on the tensile strength of entire plates of large dimensions o steel and of the best quality of American flange plate iron. Experiments on small specimens give but unreliable information as to the qualities of the material in large masses.]

TRANSLATION OF ENGINEER-IN-CHIEF E. CORNUT'S PAPER.

A number of experimenters are now engaged in investigating the changes which occur in the physical properties, in the resistance to extension, and in the limit of elasticity and ductility of iron and steel under the influence of temperature.

I do not intend to discuss the subject, but only to call attention to a certain *hot short* (*Etat Rouverain*) condition of iron and steel corresponding to a temperature which has been approximately ascertained within moderate limits.

Mr. Charles Walrand, the engineer of the steel and iron works of the Northeast Company at Valenciennes, has published on this subject in the "Industrial Annals," of June 11, 1822, a very interesting article of which I will give you a rapid summary.

Mr. Walrand says, that Mr. Valton, on his return from a visit to Russia, showed a fact which he had observed in the steel works of Prince Demidoff. He bent several times to a right angle a round steel bar previously highly heated; and remarked that when the temperature on lowering, arrived at the iris blue color, the metal became brittle. He concluded, "*That when steel is heated to a temperature between 473 degrees Fahrenheit and 662 degrees, the mettle was more brittle between those limits than at a much lower or at a much higher temperature.*"

Mr. Walrand then undertook various experiments on iron and steel of different qualities. He forged two bars of 1 centimetre (0·393708 of an inch square) of each quality of metal tested. One of these test pieces was bent cold; the other was bent hot when it reached the iris blue color, which was ascertained by a touch of the file. The following figures represent the results of these practical trials.

Mr. Walrand asserts that, "We have found in all our experiments a greater brittleness in the heated metal than in the cold metal. This brittleness appears to be accompanied by an increase in the tensile strength of the steel and by a decrease in its ductility. We have made experiments on the tensile strength of round bars, 1·6 centimetre (0·6299328 inch) in diameter, and 1 decimetre (3·93708 inches) long between the clamps."

The following table* contains the results of these trials:

Metal tried.	Temperature Ordinary atmospheric.		Temperature 617 degrees Fahrenheit.		Remarks.
	Breaking strain in pounds per square inch of cross section.	Increase of length in inches.	Breaking strain in pounds per square inch of cross section.	Increase of length in inches.	
Swedish iron..........	50918	1·2008	67274	0·7480	Bright fracture blue color.
Creusot iron............	52198	1·2008	68554	0·6496	Ditto.
Boiler steel plate....	60162	1·2638	77230	0.7480	Ditto.
Angle steel for boilers.........................	73674	1·0866	93728	0·5906	Fracture, chisel blue.
Cannon steel...........	88608	0·8780	106956	0·4724	Ditto.
Spring steel......	103542	0·7284	122743	0·3937	Ditto.

In the following table are the increase in tensile strength, and the diminution of the ductility, or lengthening of the metals, under the strains, due to the temperature of 617 degrees Fahrenheit, expressed in per centum of the values obtained at the ordinary atmospheric temperatures.

Metal.	Increase of tensile strength at 617° Fahrenheit over that at ordinary atmospheric temperatures in per centum of the latter.	Less increase of length at 617° Fahrenheit than at ordinary atmospheric temperatures in per centum of the latter.
Swedish iron................	32·12	37·70
Creusot iron..................	31·33	45·90
Boiler iron....................	28·37	40·81
Angle iron.........	27·22	45·65
Cannon steel.................	20·71	50·68
Spring steel..................	18·54	45·94

In 1878 there was published in the "Annales des Mines," a summary of the remarkable experiments on the tensile strength of iron and steel

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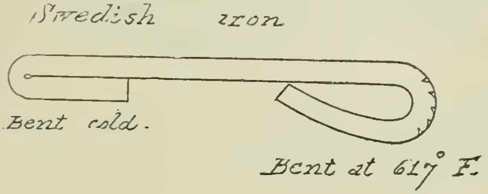
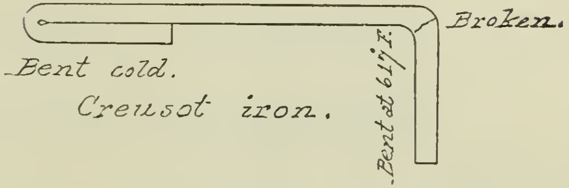
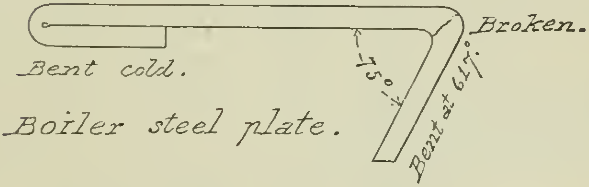
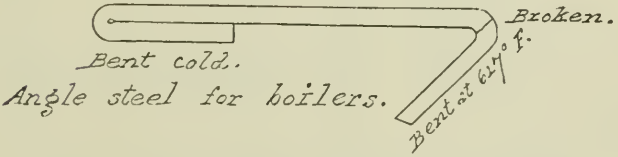
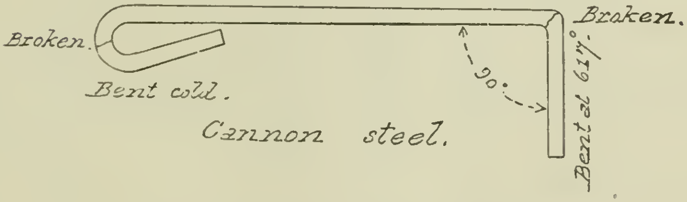
* See accompanying illustration.

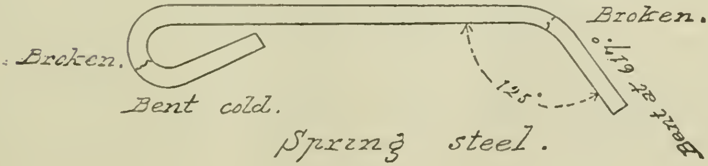

Swedish iron
Bent cold.
Bent at 617° F.


Broken.
Bent cold.
Creusot iron.
Bent at 617° F.


Broken.
Bent cold.
75°
Boiler steel plate.
Bent at 617°.


Broken.
Bent cold.
Angle steel for boilers.
Bent at 617° F.


Broken.
Broken.
Bent cold.
90°
Cannon steel.
Bent at 617°.


Broken.
Broken.
Bent cold.
125°
Spring steel.
Bent at 617°.

boiler plate at ordinary atmospheric temperatures, and at the temperatures of 572 and of 932 degrees Fahrenheit, made by Mr. Charles Huston. I shall cite the results corresponding to the temperature of 932 degrees, although they do not directly concern the subject of our inquiry.

Table containing the results of the experiments made by Mr. Charles Huston, on the tensile strength of iron and steel boiler plate at different temperatures.

	Breaking strain in pounds per square inch of the original cross section of metal.			Diminution of the cross section of the metal in per centum of the original cross section.		
	Ordinary atmospheric temperature.	At 572 degrees Fahrenheit.	At 932 degrees Fahrenheit.	Ordinary atmospheric temperature.	At 572 degrees Fahrenheit.	At 932 degrees Fahrenheit.
CHARCOAL IRON.						
No. 1	56493	66933	70118	28·00	23·50	22·00
No. 2	52297	59295	62794	26·00	22·50	21·00
No. 3	57289	62993	63092	24·00	23·50	21·00
Means of the three	55360	63074	65335	26·00	23·17	21·23
Per centum of gain	....	13·95	18·03	....	....	....
Per centum of loss	....	....	....	....	10·88	17·69
MARTIN-SIEMENS STEEL (REMARKABLY MILD).						
No. 1	51387	66691	61681	50·00	40·00	32·00
No. 2	55782	66335	64230	50·00	41·00	36·00
No. 3	56593	65197	67089	41·00	32·00	32·50
Means of the three	54587	66074	64334	47·00	37·66	33·50
Per centum of gain	....	21·05	17·85	....	....	....
Per centum of loss	....	....	....	....	19·85	28·72
INGOT STEEL OF ORDINARY MILDNESS; DOES NOT TEMPER.						
No. 1	61585	66790	65396	37·00	37·00	21·00
No. 2	67985	68582	69592	35·00	29·00	22·00
No. 3	62395	72394	70787	37·00	24·00	22·00
Means of the three	63988	69255	68592	36·33	30·00	21·66
Per centum of gain	....	8·22	7·20	....	....	....
Per centum of loss	....	....	....	....	17·42	41·29
CAST STEEL TAKING A SLIGHT TEMPER.						
No. 1	77884	79491	81696	28·00	13·25	16·25
No. 2	77784	87797	81994	28·00	23·00	22·00
No. 3	79392	80999	67985	24·00	12·00	22·00
Means of the three	78353	82762	77225	26·66	16·08	20·08
Per centum of gain	....	5·63	....	....	....	....
Per centum of loss	....	....	1·13	....	39·59	24·64

Mr. Huston heated the specimens by means of a blow-pipe in order to obtain a constant temperature during the experiments; a hole drilled in each specimen was filled with an alloy fusible at the required temperature. The composition, centessimally, of these alloys was as follows, by weight:

For 572° Fahrenheit	Zinc,	32·3.
	Lead,	67·7.
For 932° Fahrenheit	Silver,	24·5.
	Lead,	75·5

The three specimens of each kind of metal were cut adjacent from the same plate; nevertheless, the charcoal iron did not show perfect homogenousness. The Martin-Siemens steel was the most homogenous. The cast steel was the hardest and least homogenous.

If comparison be made of the figures which correspond to the temperature 572 degrees Fahrenheit, with those which correspond to ordinary atmospheric pressures, the following results will be obtained:

	Increase of tensile strength at 572° Fahrenheit over that at ordinary atmospheric temperatures in per centum of the latter.	Diminution of the cross section of the metal in per centum of the original cross section.
Charcoal iron	13·95	10·88
Martin-Siemens steel (remarkably mild)	21·05	19·85
Ingot steel of ordinary mildness; does not temper	8·22	17·42
Cast steel taking a slight temper	5·63	39·59

The conclusion from these experiments will then be the same as that from the experiments of Mr. Walrand, namely: *At the temperature of 572 degrees Fahrenheit, iron and steel have more tensile strength and less ductility than at ordinary atmospheric temperatures.*

It is to be regretted that Mr. Charles Huston did not make analogous experiments to those of Mr. Walrand on the brittleness of the metals at the temperature of 572 degrees Fahrenheit.

Unfortunately I can only submit, in this connection, a communication which proves the subject to be still very obscure. Mr. Kraft, the engineer-in-chief of Seraing, has sent me the following extract from the proceedings, May 6, 1881, of the association of engineers graduated from the school of Liège:

Mr. Greiner presented the results of some experiments which he had made for the purpose of ascertaining the influence of temperature on the tensile strength of steel. He operated on round bars 7·87416 inches long, and 0·590562 inch diameter. In submitting two identical bars to traction, one at the ordinary atmospheric temperatures, the other at about the temperature of 572 degrees Fahrenheit, which is that of smoking wood or boiling oil, Mr. Greiner found notable differences in the tensile strength, and especially in the lengthening of the bars at rupture.

The experiments were made on steel of the four great classes of the Seraing scale, which are characterized by the following properties:

	Per centum of carbon.	Breaking strain in pounds per square inch of cross section of metal.	Increase of length in per centum of the original length.
1st Class (extra mild)................	0·05 to 0·20	56891 to 71114	27 to 30
2d Class (mild)...........................	0·20 to 0·35	71114 to 85337	20 to 15
3d Class (hard)...........................	0·35 to 0·50	85337 to 99560	15 to 10
4th Class (very hard).................	0·50 to 0·65	99560 to 113783	10 to 5

All commercial steel belongs to one of these four classes.

The experimental results are given in the following table:

	At ordinary atmospheric temperatures.		At the temperature of 572 degrees Fahrenheit (annealing blue).	
	Breaking strain in pounds per sq. in. of cross section of metal.	Increase of length in per centum of the original length.	Breaking strain in pounds per sq. in. of cross section of metal.	Increase of length in per centum of the original length.
1st Class ...	62580	26	49780	11·4
2d Class....	81070	19	69692	10·0
3d Class.....	89601	20	72536	8·7
4th Class...	105249	16	85337	7·25

As a general result there is a diminution of 20 per centum in the tensile strength, accompanied by a diminution of 50 per centum in the lengthening or stretching.

Mr. Greiner is in accord with Messrs. Walrand and Charles Huston that steel at the temperature of 572 degrees Fahrenheit is a great deal less ductile, and consequently more brittle, than at ordinary atmospheric temperatures; but he is not in accord with them on the results of the heating of the metal in regard to its effect upon the tensile strength. Mr. Greiner found the tensile strength to diminish, Messrs. Walrand and Charles Huston found it to increase by heating.

If, as in the previous cases, there be made a table of the differences, the following will result:

	Diminution of tensile strength at 572 degrees Fahrenheit below that at ordinary atmospheric temperatures in per centum of the latter.	Less increase of length at 572 degrees Fahrenheit than at ordinary atmospheric temperatures in per centum of the latter.
1st Class	20·45	56·15
2d Class	14·03	47·37
3d Class	19·05	56·50
4th Class	18·92	54·69

On this subject I have consulted my friend Mr. Barba, principal engineer at Creusot, whose competence in these matters is well known. He regards as absolutely certain the fact that *towards 572 degrees to 662 degrees Fahrenheit, iron and steel pass into a peculiar hot short state* (*Etat Rouverain*). He adds:

> At the same time as regards experiments on the tensile strength, the resistance *appears* to increase, the limit of elasticity *appears* to diminish, as well as the amount of stretching or lengthening at the moment of rupture. I say *appears*, because our experiments on this subject are not numerous enough to make these results certain.

This hot short state (*Etat Rouverain*) appears then to me impossible of discussion by existing data; all investigators admitting that new experiments are necessary to determine the exact conditions of its formation according to the nature of the metal, and of its influence on the tensile strength and the limit of elasticity. But the knowledge that there is such a state, furnishes a satisfactory explanation of some accidents which happen to metals. Thus Messrs. Krafft, Barba and Walrand attribute to this *Etat Rouverain* the fracture of the friction bands of brakes in consequence of too intense action.

As regards the construction of steam boilers, this *Etat Rouverain* enables us to assign a cause for the fracture of their curved ends and of their flanges in the case of excellent metal worked hot. In fact, it is enough for the boiler maker to continue heedlessly turning a flange after the metal has fallen to the iris blue temperature, to produce a slight crack in the turn; this crack will increase under the ordinary contraction and dilation of a boiler in use, and become dangerous in time if not discovered by minute inspection.

To this *Etat Rouverain*, I believe, should also be attributed the many breakages produced in the plate of a boiler when it is thickened by upsetting the metal with a hammer after being slightly heated in position.

Further, I know this particular state of brittleness in iron and steel when approaching the temperature of 572 degrees Fahrenheit, to be so well understood in our great iron-working establishments, that their blacksmiths are directed not to continue forging after the iris blue color appears.

Cores for Melted Steel.—M. Gladsden has devised certain improvements in ventilating cores, which are designed to facilitate the escape of gases during the flow of melted metals, in order to avoid blow-holes. In the centre of the mould there is attached, by a bolt upon the metal plate which supports the mould, a perforated iron tube placed vertically. Around this tube, when there are to be large castings, is rolled a cord of hay, straw, or other like material. This vegetable córd is coated with silex, pure or nearly pure, with the addition of some mild liquid, such as glue, water, or sour beer. If the pieces are of more moderate dimensions the coating of silex is applied directly to the metallic core. Refractory cores and perforated metallic cores have already been used independently, but Gladsden claims priority for the combination of the two methods. The entrance of the metal may be made either from above or still better from below; the slag will then be lifted to the upper level of the core, while the gases escape by the centre, through the silicious coating.—*Chron. Industr.*, April 13, 1884. C.

Cleansing of Liebig's Statue.—This marble statue, which was inaugurated at Munich in the month of August, 1883, was sometime afterwards covered with brown spots, which were absolutely ineffaceable by the ordinary methods. The members of the commission, which was appointed to study the nature of the spots and try to effect their removal, have just published an account of their labors in the Bulletin of the Berlin Chemical Society. The analysis of the spotted portions of the statue showed the presence of silver and of manganese; hence it was concluded that the spots had been produced by a mixture of permanganate of potash and nitrate of silver. A series of experiments showed that the spots could be dissolved by transforming the silver and the manganese into soluble sulphurets. In order to effect the transformation, the spots were covered at many different times with kaolin, in a paste soaked with sulf-hydrate of ammonia. Washing with water then made the excess of alkaline sulphuret disappear. It was then only necessary to dissolve the sulphurets in cyanide of potassium with which a layer of kaolin was soaked. The operation perfectly succeeded, to the great satisfaction of the savans of all countries.—*Genie Civil; Chron. Industr.*, April 27, 1884. C.

MODERN RAILROAD FACILITIES.*

By Wm. Barnet Le Van.

HISTORY.

Eighty years ago, Oliver Evans, who deserves at this day all the honor that can be conferred on man as one of Philadelphia's noblest sons, made the first application in the streets of this city of steam to a carriage in America, and, in fact, the first locomotive engine. This experiment was more successful than any that had preceded it.

About this time, Evans publicly stated that "The time will come when people would travel in stages, moved by steam engines, from city to city, almost as fast as birds fly—fifteen or twenty miles an hour—passing through the air with such velocity, changing the scene in such rapid succession, and with the most exhilarating exercise. *A steam carriage will set out from Washington in the morning—the passengers will breakfast in Baltimore—dine in Philadelphia, and sup in New York the same day.*"

"To accomplish this, two sets of railways will be required, laid so nearly level as not to deviate more than two degrees from a horizontal line—made of wood or iron, or smooth paths of broken stone or gravel, with a rail to guide the carriages, so that they may pass each other in different directions, and travel by night as well as day." It is a singular coincidence that Evans should have made one of the first experiments in propelling a carriage by steam in the very city destined to become, in the course of fifty years afterwards, the head centre of one of the most important railroads in the world—"The Pennsylvania."

The Fastest Railroad Trains in the World.—As there has been considerable discussion of late as to which road runs the quickest trains, I have collated from the different time tables and other sources the best time made, that the community at large may know what is being done both at home and abroad. England stands first, both as to the number and the quickest runs, as follows:

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* A paper read at the Stated Meeting of the Franklin Institute, Wednesday, December 17, 1884.

A Summary of the Fastest Trains in the World.

Name of Road.	Between	Distance in miles.	Time. H. M.	Running average.	Number of trains.
Baltimore and Ohio	Baltimore and Washington	40	·45	53⅓	2
Manchester, Sheffield and Lincoln	Manchester and Warrington	16	·18	53⅓	16
Great Western	Paddington and Swindon	77⅛	1·27	53⅕	4
Great Northern	Hitchin and Peterborough	44¼	·50	53	1
"	Grantham and Doncaster	50½	·58	52¼	1
"	Grantham and London	105½	2·04	51	2
"	Grantham and York	82½	1·39	50	2
North Western	Northampton and Willesden	60¼	1·10	51⅔	1
"	Rugby and Willesden	77¼	1·32	50⅓	1
Midland	Liverpool and Stockport	37¾	·45	50⅓	4
"	London and Kettering	72¼	1·27	49⅘	1
"	Bedford and Kentish Town	48	1·00	48	10
"	Leicester and St. Poncras	99¼	2·07	47	1
North Eastern	York and Darlington	44¼	·53	50	1
Caledonian	Carlisle and Beatlock	39¾	·48	49⅔	1
"	Carlisle and Carstairs	73½	1·31	48½	1
Bound Brook	Trenton and Bound Brook	27·1	·31	50	1
"	Jersey City and Philadelphia	89·4	1·52	47·9	2
"	Philadelphia and New York	90·4	2·00	45·2	2
Pennsylvania	Germantown Junction and Jersey City	84·3	1·44	49·4	2
"	Philadelphia and Jersey City	89·7	1·53	47·1	2
"	Philadelphia and New York	90·7	2·00	45·2	2
North British	Polmont and Cowlairs	23½	·29	48·6	1
Great Eastern	Lincoln and Spalding	38¼	·47	48⅚	3
Glasgow and Western	Carlisle and Dumfries	33	·42	45	1
Brighton	London Bridge and Brighton	50½	1·05	46⅗	1
Chatham and Dover	Herne Hill and Dover	74½	1·36	46¼	1
South Eastern	London and Dover	74½	1·39	45	2
Berlin and Cologne		404	9·00	47·1	1

Manchester, Sheffield and Lincoln.—This railway runs the greatest number of fast short distance trains in the world, numbering sixteen daily, between Manchester and Warrington, a distance of sixteen miles in *eighteen minutes*; running time 53·3 miles an hour. Fourteen of the above miles are practically level. None of these are very heavy trains, and their punctuality is excellent.

Great Western.—This line is unique in its track, which is broad gauge (seven feet) from Paddington to Penzance—mixed gauge as far as Exeter—and most of its system is laid with *longitudinal* sleepers, the same as in use on our city passenger railways. It has the smoothest running track in the world, and the speed between Paddington and Swindon is the highest of any long run in England.

For years this road was far ahead in speed, the flying trains known as "Dutchman," running just as they do now about twenty years ago. In fact on June 13, 1846, an experimental trip was made by the new locomotive, "The Great Western." The train weighed one hundred tons. The train started from Paddington and arrived at Didcot in fifty-four minutes; distance fifty-one miles, or at the rate of fifty-six miles an hour.

This company runs four express trains to Exeter, a distance of 194 miles, at the rate of 46½ miles an hour; the distance between Paddington and Swindon, 77 miles, is run in *one hour and twenty-seven minutes*, or at the rate of 53⅕ miles an hour. (The two afternoon trains are called "Zulu," because they began to run the day after the Prince Imperial of France was killed—the two morning ones are the "Dutchman.") The running average of the four Plymouth trains, *between Exeter and Paddington*, is as high as 50⅓ miles an hour (distance 194 miles), and the distance between Taplow and Swindon, which is very smooth and level, the 55 miles is covered within the hour, but as the speed is so uniform it does not attract the attention of the passengers, and they are surprised if they undertake to time it with their watches.

Great Northern.—The most of the trains on this road are very long, but they are run at very high speed with unusual punctuality. In 1880 this road ran four express trains to Leeds, which covered the distance between Grantham and Wakefield, 70 miles, in *seventy-eight minutes*, or on an average of 53·8 miles an hour, which is slightly faster than the Swindon trains above mentioned; for some reason these trains have been discontinued. Now, on Sundays, the 5·00 P. M. runs from Hitchin to Peterborough, 44·25 miles in *fifty minutes*, or an average of 53 miles an hour. This road also runs trains between Grantham and Doncaster, 50½ miles in *fifty-eight minutes*, or an average of 52·25 miles per hour every day. This road has forty-nine long runs, averaging 73¾ miles at a running average of *fifty miles* per hour. The longest run is made from King's Cross, London, to Grantham, 105½ miles in *two hours and four minutes*, running average of 51 miles an hour.

London and North Western.—This is the oldest established railway company in England, and does the largest business, it being the first built and has the lightest grades, but in point of speed is far behind other companies. The train carrying the Irish mail to Holyhead, from Euston Station (London), over this line, and dubbed years ago "The Wild Irishman," has now sunk into comparative obscurity with its rate of 42 miles an hour. Its fastest trains are between Northampton and Willesden a distance of 60¼ miles, which is covered in *seventy minutes*, an average of 51⅗ miles per hour, also between Rugby and Willesden, 77¾ miles, is covered in *ninety-two minutes*, or an average of 50½ miles per hour. There are twenty trains between Liverpool and Manchester, distance 31½ miles, in *forty-five minutes*, averaging 45 miles an hour.

English Long-distance Train.—North Western Limited Mail.
(Third Class.)

Between	Miles.	Time.	Miles per hour.
Euston (leave)		8·50	45
Rugby	82¾	10·40	
		10·44	45
Tamworth	110	11·20	
		11·24	45½
Stafford	133½	11·55	
		11·59	44½
Crewe	158	12·32	
		12·38	46¾
Wigan	194	1·24	
		1·30	40
Preston	209¼	1·53	
		1·57	40·6
Carlisle	299¼	4·10	
		4·18	48½
Carstairs	372¾	5·53	
		6·00	36
Holytown Junction	389	6·27	
		6·29	
Coatbridge	393¼	6·37	—
		6·40	
Larbert	409	7·03	40½
		7·07	
Stirling	417¼	7·21	—
		7·24	
Perth (ticket station)	450½	8·13	40
		8·15	
Perth (leave)		9·05	39⅓
		9·55	
Forfar	482¾	9·69	32
		10·28	
Bridge of Dun	498¼	10·29	37
		11·37	
Aberdeen (ticket station)	540¼	11·40	

Actual miles per hour ....36·4 Actual running miles per hour............41·8

French Long-distance Train.—Paris, Lyon and Mediterranée.
("*First Class Only.*")

Between	Miles.	Time.	Miles per hour.
Paris	....	8·55	36
Montereau	49	10·17	
		10·20	41½
Laroche	96½	11·28	
		11·31	41¾
Tonnerre	122¼	12·08	
		12·33	39½
Dijon	195½	2·24	
		2·29	42
Macon	273¾	4·21	
		4·26	34½
Lyon	314¾	5·37	
		6·08	40
Valence	383¾	7·51	
		7·56	42½
Avignon	460¾	9·45	
		9·50	38⅔
Marseilles	536	11·47	

Actual miles per hour........................36 Actual running miles per hour...... 39¾

Midland.—This road is remarkable for very high speed, although it has very heavy grades to contend with. It, like the Pennsylvania Railroad, is noted for its energy in developing "through" services and the opening up of branch lines connecting with its own. The scenery on this line also, like the Pennsylvania, is grand, including some of the loveliest views in England.

A celebrated writer in England suggests that this road "should run a car with projecting glass sides and cheap fares, for factory hands, to see the sights there are between Leeds and Carlisle." Observation cars, such as are run by the Pennsylvania Railroad in this country, between Altoona and Cresson, would answer a better purpose. The views between Derby and Manchester are grand, and the panorama seen from the Westmoreland heights as you "spin" along down grade, at 70 miles an hour, are beyond description. The locomotives of this road, like those on the Pennsylvania, have nearly one-third of their time occupied in ascending very steep grades, but they accomplish their task well. The highest point on this road being 1,015 feet above the sea. There are four trains run between Liverpool and Stockport, 37¾ miles in *forty-five minutes*; running average 50⅓ miles an hour, and one between St. Pancras (London) and Kettering, 72¼ miles in *eighty-seven minutes,* running time 49·8 miles an hour, and between Bedford and Kentish-Town 48 miles in *one hour.*

North Eastern.—This line is more noted for dividends than fast running, from the fact of easy grades. It has the most comfortable equipment of trains in England, and with all, the most "democratic." Its *third class cars* are so inviting that even a "dude," entering by mistake, has been known to travel from York to Newcastle without loss of respectability. This company is also "democratic" enough to "honor America's invention in regard to *brakes*; almost every train, on a small branch, has the Westinghouse automotic." The excursion rates on this line are the lowest in England. The train between York and Darlington, a distance of 44¼ miles, is run in *fifty-three minutes,* an average of 50 miles an hour. From York to Newcastle, 80¼ miles is covered in *one hour and forty-two minutes,* running average 47⅕ miles per hour. This line mounts up to 1,369 feet above the sea, on Stainmoor, where it crosses the boundary of Yorkshire and Westmoreland. This is the highest passenger route in England, and has more romantic and beautiful views than any others. These abound either on the sea-coast, from Flamborough to Berwick, or along the valleys.

Great Eastern.—This line, like the North Eastern, has fitted all its trains with the Westinghouse brake. This line follows the curve of the east coast, and is thus continually crossing (little) transverse valleys; the greatest height between Colchester and Yarmouth is only about 125 feet above the sea, near *Westerfield.*

The best long distance run is between Norwich and Doncaster, 163 miles (seaside express), in *three hours and thirty-five minutes,* a running speed of 47½ miles an hour. The fastest run is made between Lincoln and Spalding, 38¼ miles in *forty-seven minutes,* averaging 48¾ miles an hour.

London, Brighton and South coast.—Brighton being the Long Branch of England, and formerly the residence of the king of England, who, according to an act of Parliament must live within *fifty miles* of London. This has been the means of making the place a popular resort. The expresses on this road, like all running to sea-side resorts, have very heavy trains.

The best run between London Bridge and Brighton, 50½ miles, is covered in *sixty-five minutes*, an average of 46·6 miles an hour.

London, Chatham and Dover.—This line deserves great credit for the spirited way in which it runs over its hilly route. The 74 miles between Herne Hill and Dover is covered in *one hour and thirty-six minutes*, an average of 42¼ miles an hour.

London and South Western.—This line is almost level to *Basingstoke*, and gets steeper as it goes west. There are three expresses and thirteen long runs, averaging 47⅓ miles. The *longest* and quickest is from Yeovil Junction to Exeter 48·5 miles in *sixty-three minutes*, an average of 46·6 miles an hour.

South Eastern.—This line has steep grades except where the line runs between Tunbridge Junction and Ashford, nearly at sea level, and quite straight for 20 miles. The distance by Cannon street, London and Dover, 74½ miles, is covered in *ninety-nine minutes*, or at the rate of 45 miles an hour.

Scotch Lines.—There are three Scotch companies that run fast express lines, and they do this over a line beset with grades.

Caledonian.—This line runs fast expresses, but owing to the steep grades of unusual length, the running average is below the former lines. If a passenger wishes to see what 70 miles an hour means, he can on this line readily be satisfied, and nowhere better than here ascertain how little compensatory effect a speed of *seventy* miles an hour, down a grade of $\frac{1}{75}$, can have in making good the loss of time going *up* the other side. On this line, between Carlisle and Beattock, 39·75 miles, are covered in *forty-eight minutes*, averaging 49⅔ miles an hour, and between Carlisle and Carstairs, by the Limited Mail, 73·5 miles is spanned in *ninety-five minutes*, or an average of 48·5 miles an hour.

North British.—This line runs the Midland (England) expresses between Edinburgh and Carlisle, and also runs a local express of its own between Edinburgh and Glasgow. Between Polmont and Cowlairs, a distance of 23·5 miles, is covered in *twenty-nine minutes*, or at the rate of 48·6 miles an hour; and between Carlisle and Edinburgh 98·25 miles is run in *two hours and twenty minutes*, averaging 42 miles an hour.

Glasgow and South Western.—This line is a much easier one than the two former, the highest point reached being only 625 feet above the sea. The Midland (England) cars are run by this line between Glasgow and Carlisle; and between Carlisle and Dumfries, a distance of 33 miles, is run in *forty-two minutes*, or an average of 47 miles an hour; between Dumfries and Kilmarnock, 58½ miles, in *one hour and eighteen minutes*, or at the rate of 45 miles an hour.

Berlin to Cologne.—By the Lehrte route, stopping for dinner at Hanover, viz., Hanover and Stendal. The distance from Berlin to Cologne by this route is 404 miles, and is spanned in *nine hours*, or an average of 47·1 miles an hour.

Fastest English Long-distance Train.—(*East Coast Route.*)

	Miles.	Hours. Minutes.	Miles per hour.
Glasgow..............(leave)............	....	8·40	
Cowlairs........................	1½	8·46	
		8·48	45½
Polmont Junction........................	25	9·19	
		9·20	42
Haymarket	46	9·50	
		9·52	
Edinburgh, (Waverly Station)........................	47¼	9·55	
		10·00	46
Berwick........................	104¾	11·15	
		11·20	47
Newcastle........................	171½	12·45	
		12·50	45
Darlington	207½	1·38	
		1·41	49⅙
York (refreshments)........................	251¾	2·35	
		3·05	50
Grantham........................	334¼	4·44	
		4·50	48¾
King's Cross (London)	439¾	7·00	

The *North British* Company runs these trains between Glasgow and Edinburgh, the *North Eastern* between Edinburgh, and the *Great Northern* between York and London.

This time table is the fast express known as the "Flying Scotsman," which also leaves King's Cross (London) at 10 A. M., stops an hour for dinner at York, and reaches Waverly Station, in Edinburgh, at 7 P. M., distance 439¾ miles.

Average miles per hour from King's Cross to Edinburgh, 48, and Edinburgh to Glasgow being 47 miles per hour.

French Fast Long-distance Train.—Paris, Orleans, Tours, Bordeaux.
(*First Class.*)

Between	Miles.	Time.	Miles per hour.
Bordeaux (Bastide)..........(dep.)..........	....	7·50 8·21	42
Libourne..........	21¾		
Coutras..........	31¾	8·23 8·39	37½
Angoulême..........	82¾	9·50 10·15	44⅓
Ruffec..........	112	10·56 10·59	42·8
Poictiers..........	153	11·55 12·00	44
Chatellerault..........	173¼	12·30 12·32	40½
St. Pierre des Corps..........	215½	1·30 1·35	43¾
Blois..........	248½	2·20 2·22	44
Les Autrais..........	285	3·10 3·15	45⅔
Etampes..........	324	4·07 4·10	45⅓
Paris..........	359¼	4·56	45⅓

Actual miles run per hour.........39½ Actual running miles per hour.........43¾

AMERICA.

Baltimore and Ohio Railroad.—This road, in times gone by, has marked many an epoch in railroad history, and, as the first passenger railroad in the world, has ever been in the lead in important steps forward. Building its own locomotives, which for half a century have been accorded the highest place in America, with its grand motive-power, and superb equipment throughout, it makes the fastest short distance time in the United States, and second to none abroad.

This road, on its Baltimore and Washington line, forty miles long, covers the distance in *forty-five minutes*, being at the rate of 53·3 miles per hour. There are also four trains spanning the distance in *fifty minutes*, averaging 48 miles an hour.

Philadelphia and Reading Railroad, Bound Brook Division.—This road follows next in order. This line runs a train to and from New York and Philadelphia in *two hours*, including the ferrying across the North River at the former place. The distance between the cities is by this route 90·4 miles, *via* Ninth and Green streets. This distance is covered in the above time, an average of 45·2 miles per hour. The train time between Philadelphia and Jersey City, including four stops, and one change of locomotive, is *one hundred and twelve* (1 hour and 52 minutes) *minutes*, distance 89·4 miles, is run at the rate of 47·93 miles per hour; and between Trenton and Bound Brook, 27·1 miles, is covered in *thirty-one minutes*, or an average of 50 miles an hour. There are a few really fine bits of running on this line. The writer has several times averaged *seventy miles* an hour for five successive minutes from Skillman east, this portion of the road being straight for a distance of 14 miles. The alignment of this line is very favorable, none of the curves exceeding two degrees between Jenkintown and Jersey City.

Pennsylvania Railroad, New York Division.—This line also runs a train from Philadelphia to New York, distance 90·7 miles, in two hours, making one stop, including ferryage at New York, averaging 45·4 miles an hour. Between Philadelphia and Jersey City, 89·7 miles, including one stop, the time is *one hour and fifty-three minutes*, averaging 47·1 miles an hour; and between Germantown Junction and Jersey City 84·3 miles is covered in *one hour and forty-nine minutes*, or at a rate of 49·4 miles an hour.

This route is unfortunately a continuous series of curves and re-curves, ninety in number, varying from one degree (5,730 feet) to nine degrees (636 feet radius) radius.

With all these drawbacks, the Pennsylvania Railroad Company every day accomplish a speed of nearly *fifty miles an hour*, passing over the number of curves before stated, whose total curvature would describe over ten complete circles.

But in long distance runs the Pennsylvania Railroad stands first in the world. The New York and Chicago Limited train covers the the distance between the two cities, 912·2 miles, in *twenty-six and one-half hours*, including the ferryage at New York and eight stops which occupy *sixty-six minutes*, being an average running time of 36·18 miles per hour. From Chicago to Fort Wayne, a distance of 148 miles, is covered in *four hours*, an average of 37 miles an hour.

In fact, there are no such distances yet run in Europe as across the American continent by the Chicago limited. By this train the most luxurious traveling in the world is done, besides the speed is the fastest of any long distance train. This train is made up and composed exclusively of drawing-room, dining-room, smoking-room and sleeping cars, the baggage and kitchen composing one car. The sleeping car charge and "extra fare" are represented in the one "extra fare" ticket. No half "extra fare" tickets are sold; children between five and twelve years of age being required to purchase whole "extra fare" tickets, in connection with half-fare passage tickets. Extra fare tickets include a double berth in sleeping car or seat in section of same. A double berth will hold two persons; a section contains two double berths, and a drawing-room contains two double and two single berths. Two persons desiring to occupy the same berth will be charged one and one-half the extra fare. At least one passage ticket and one extra fare ticket will be required for each double berth occupied.

The Fastest Long-distance Train in the World.—New York and Chicago Limited.

Between	Miles.	Time.			
		Hours. Minutes.	Minutes lost in ferriage & stops.	Minutes.	Miles per hour.
		A. M.			
New York City (Eastern time)	....	9·			
Jersey City	1·	9·08	8		
Jersey City	....	9·15	7		
Philadelphia (Broad Street Station)	89·7	11·14			
....	....	11·25	11	119	45·4
Harrisburg	105·2	P. M. 2·05			
....	....	2·10	5	160	39·49
Altoona	131·6	5·35			
....	....	5·40	5	205	38·46
Pittsburg	116·7	9·00			
(Central time)	....	8·17	17	200	35·
Alliance	83·	11·07			
....	....	11·12	5	170	29·26
Crestline	106·	A. M. 2·27			
....	....	2·30	3	195	32·6
Fort Wayne	131·	6·			
....	....	6·05	5	210	35·9
Chicago	148·	10·30	....	265	33·33
Totals	912·2	26·30	1·06	25·24	289·44
Average miles per hour	....	....	....	....	36·18

The dining cars are on the western plan, not restaurant cars. *Table d'hôte* meals are served at the fixed price of $1, from bills of fare, representing all the substantials and delicacies of the season, which can hardly be matched in the country for cleanliness, juiciness and variety. The smoking-room cars are supplied with easy chairs and lounges, instead of stiff pews. You can take a seat in a rattan chair made deep and with soft cushions, or take your place at a writing desk on which is paper printed with the name of the Limited Express, and with a library of books above you, and be waited upon by a wag of a black porter, who will bring in drinks of any kind, cigars and lunch, with cards and card tables at hand. A trip across the continent in one of these trains is a luxury fit for a king, and just the thing to rest a wearied merchant or official, the landscape passing so rapidly and the time made in general with great thoroughness.

Fastest Long-distance Runs in the World.—Arranged According to Distance.

Name of Road.	Between	Miles.	H. M.	Running Average.	Train.
Pennsylvania	Chicago and Ft. Wayne.	148	4·04	36·4	New York & Chicago, Limited.
"	Altoona and Harrisburg	132	3·20	39·5	
"	Pittsburg and Altoona	117	3·15	36	
Great Northern (Eng.)	Grantham and King's Cross	105½	2·05	51	Fast Express fr Manchest'r
Midland "	St. Pancras & Leicester	99¼	2·07	47	Down Scotch Express.
Paris, Lyon and Mediterranèe	Laroche and Dijon	99	2·41	37	7·15 fr'm Paris 1st class only.
North British	Carlisle and Edinburgh.	98¼	2·20	42	Night Expr's.
Midland	Derby and Liverpool	91½	2·04	44¼	12 N. from St. Pancras.
"	Skipton and Carlisle	86¾	1·55	45·2	Night Expr's.
London & N. Western	Preston and Carlisle	90	2·10	41½	One each way
London & N. Western	Chester and Holyhead	84½	2·	42¼	One each way
London & N. Western	Rugby and Euston	82¾	1·50	45	One each way
Great Northern	Grantham and York	82½	1·39	50	One each way
North Eastern	New Castle and York	80¼	1·42	47⅕	One each way
London, Chatham & Dover	Victoria and Dover	78	1·45	44⅗	One each way
South Eastern	Cannon st. and Dover	74½	1·39	45	One each way
North Western	Rugby and Willesden	77¼	1·32	50⅓	
Pennsylvania	Ger'n Jun. & Jersey City	84·3	1·44	49·4	One each way
Great Western	Paddington & Swindon	77	1·27	53⅞	Two each way
Caledonian	Carlisle and Carstairs	73½	1·35	48·5	Limited Mail.
London & N. Western	Carlisle and Carnforth	62¾	1·25	44¼	" "
Midland	Bedford & Kentish Town	48	1·00	48	All Manchester Exp'ses.
Paris, Orleans, Tours, Bordeaux	Ruffec and Poitiers	41	0·56	44	
Paris, Orleans, Tours, Bordeaux	Les Aubrais & Etampes.	39	0·52	45⅓	First class.
Baltimore and Ohio	Baltimore and Washington	40	0·45	53⅓	One each way

Passengers paying so unusual a rate, are as a general thing, more exacting than first-class passengers ordinarily. The company expecting this, special notice is given to all the company's people to be considerate and patient with the passengers. This train leaves New York at 9 A. M. (eastern time), and reaches Chicago at 10·30 A. M. (central time) the next day. Returning it leaves Chicago at 4·51 P. M. (central time), and reaches New York at 7·30 P. M. (eastern time) the next day, The above time table will show how the run is made:

It will be seen by this table that the speed in America, both for short and long distance runs, is second to none obtained elsewhere.

The *average* speed in this country in long runs does not quite equal the English, but it must be remembered that our roads have heavier grades and *more* curves, the latter being of smaller radii than is allowable on England and French roads. Then, again, the law of England gives the railroad companies exclusive right over their tracks and anyone trespassing thereon is liable to fine and imprisonment. When the law in this country steps in, as in England, we will be able to far surpass her. I have been told that we are running fast enough, but speed is a means to an end, the greater the expedition compatible, with safety, the more benefit will be derived by all parties. I am, every day, also asked if there is not more danger in the running of fast trains than with slow trains. As for *safety*, the safest line is the one which is the best managed, but the one which runs the most and fastest trains, is obliged to be the best managed; thus, those who prefer *slow* trains must yet acknowledge their debt to fast trains.

Railroad mortality statistics of England and some parts of the Continent of Europe have been compiled and published in France, from which it appears that the greatest fatality occurs on the French railways:

The	French	Railroads	kill,	annually,	one	in	every.........	2,000,000
"	English	"	"	"	"	"	"	5,250,000
"	Belgian	"	"	"	"	"	"	9,000,000
"	Prussia	"	"	"	"	"	"	21,500,000
"	French	"	wound,	"	"	"	"	500,000
"	English	"	"	"	"	"	"	750,000
"	Belgian	"	"	"	"	"	"	9,000,000
"	Prussia	"	"	"	"	"	"	4,000,000

Roundly speaking, French railways kill five times as many as English. English not quite twice as many as Belgian, and Belgian nearer thrice than twice as many as Prussian, which are much the least fatal of the four.

PHYSICAL CONSTITUTION OF THE SUN.

By Prof. Charles A. Young.

(Concluded from page 220.)

The next picture will show better what you see in an ordinary telescope. This is Secchi's picture of a mature and well formed sunspot. In this the centre of the spot is nearly round, and the penumbra also. You see how the penumbra is made up of filaments that point to the centre, and how portions of these filaments are broken off and seem to move in towards the centre. If you watch them in a telescope you will see them appear to sink into the sun. Most physicists think there is in the spots an eddying current, which coming up around the outer edge from below goes down in the centre. When a spot is forming or going out of sight, we find that real changes occur very rapidly, but besides these real changes as a spot passes towards the centre of the sun from the edge, apparent changes occur in the way indicated by this next pictures, seeming to show that a sun-spot is a hollow in the solar surface. When a spot is in the centre it looks as at "*A*"; as it gets towards the edge, it takes on the appearance as at "*B*," "*C*" and "*D*," and when it gets to the edge as at "*E*" you lose sight of the spot entirely. The depth of these spots varies from twenty-five hundred to to ten thousand miles in diameter, they are anywhere from five or six thousand miles to fifty or sixty thousand miles. The first spot shown was forty thousand miles, and the second one was about twelve thou-

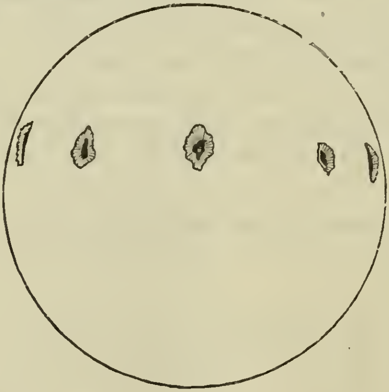


Diagram illustrating the fact that Sun-spots are Hollows in the Photosphere.

sand miles in diameter. You could have put the earth, Venus and all the other planets into some spots that have been observed.

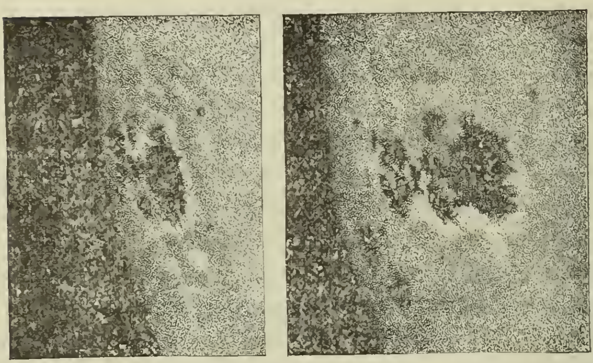
Here we have a copy of the photograph by Rutherfurd, of one spot-group on successive days. Here we have it as it first came on the surface of the sun; next you see how the spot broke up; just as whirlpools in a river appear to divide into smaller ones; first the vortex will become irregular, then it will be bridged across, and then the parts will separate and form new whirls. It very often happens that a spot will break into two, but it is seldom that two will unite in one. The size of this group, the lower one in the further corner, would be something like one hundred thousand miles across, so that the smallest of these spots would be a great deal larger than the earth.

Here are some other spots taken at the Harvard College Observatory. This is the same spot on successive days; and a few days later you see it turned partly around and then broken into pieces. Here again we have a spot in the process of dissolution. As Secchi says, "when a spot is done with, the whole neighboring surface seems to fall in pell mell," and I do not know of any better way of describing the breaking up of the spot. There is a rough and broken surface in the place of the spot which has vanished.

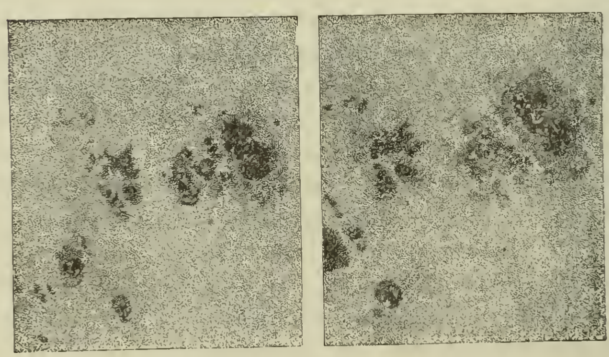
Different theories have been held as to the nature of the spots· Galileo thought they were clouds above the surface of the sun, but that is not true. Another astronomer thought they were little planets going around the sun. The idea that they are hollows in the sun's surface came later. Herschel's idea was that the sun itself was a black habitable globe covered with luminous cloud, and that breaks in this cloud permitted us to see the dark body of the sun below. I need not say that he would not maintain any such opinion to-day with our present knowledge of thermo-dynamics. The view generally held at present, is that they are hollows filled with what may be called smoke, if you will not interpret the term too literally. Faye's theory is that they are vortices, such as would be produced by storms on the surface like the storm-centres on our own globe, producing vortical cavities in the photosphere, which cavities are filled up with matter from above, I would accept this theory without hesitation, were it not for the fact that the storm centres in the northern hemisphere would necessarily rotate in one direction, and those in the southern hemisphere would rotate in the other direction, and there is no such effect observable on the sun's surface, so that on the whole I am puzzled as to what to say as to the

SUN SPOT GROUP ON SUCCESSIVE DAYS.

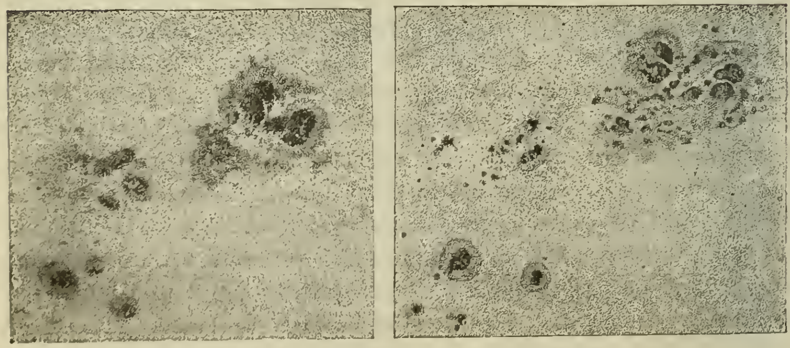
(From a Photograph by Rutherfurd.)



September 19, 1870. September 20, 1870.



September 21, 1870. September 22, 1870.



September 23, 1870. September 26, 1870.

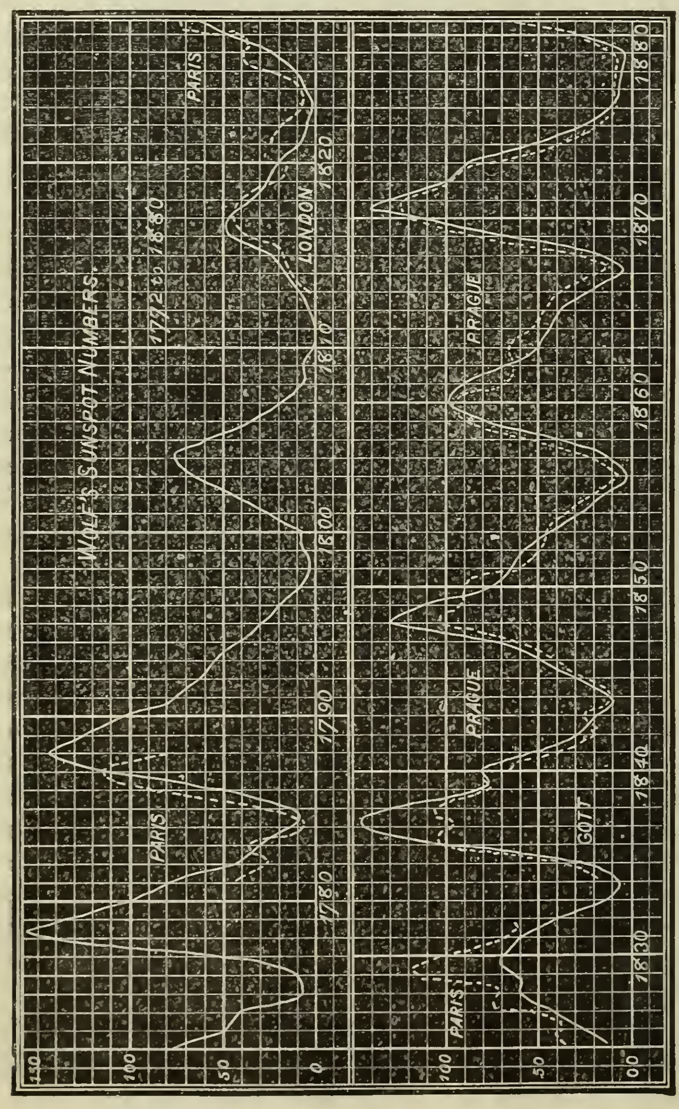
real nature of sun spots. I am certain they are cavities, but I am not sure what causes the cavities. Secchi's idea was that matter blown up from below falls back upon the sun's surface and so forms these cavities.

I have sometimes been disposed to think that things might happen in this way; the material of the sun must be more or less viscous, and it might be that an eruption at one point would lead to a "slumping in" of the surface somewhere else, so that spots are nothing but "sinks" caused by eruptions near them. It is still, however, a question of fact whether the hollow causes the eruption, or whether the eruption causes the spot. At present I do not think we are able to answer that.

I need hardly say to you that if the sun is sending such an enormous amount of light and heat it must be very hot; and what would happen if we had a mass of vapors heated in the centre and cooler on the outside? Of course clouds would be formed. We have on the sun the vapor of iron, the vapor of copper, the vapor of sodium, etc. On the outer surface of a great mass of such vapors a coat of clouds must inevitably be formed. These clouds will be of red hot iron, molten sodium, etc. Those clouds, probably in structure like our water and snow clouds but chemically made up of cast iron and all that sort of thing, are what shine upon us with such tremendous brightness, as the solar photosphere.

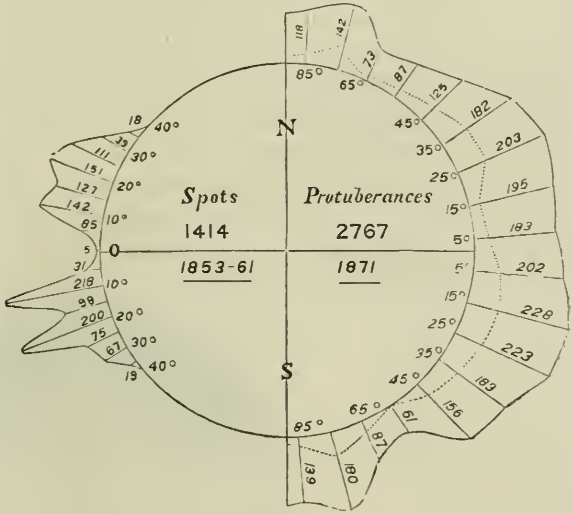
The spots have some curious ways; they do not remain regularly on the surface of the sun; they come from day to day and from week to week. Sometimes they come very frequently, and then only at long intervals. This diagram shows how they have appeared for the last hundred years; they were very frequent in 1775; there were no spots in 1777; a great multitude in 1784; none in 1788, etc. This variation constitutes what is called the periodicity of the spots. The average interval between the sun-spot years, for the past 200 years, is about eleven years; but you see there is no exact regularity about this interval. Sometimes two such years will follow each other within seven years, and then they will be separated by as much as fifteen. There has been a great deal of speculation as to the cause of this, but whether or not it will ever be discovered I cannot tell.

Another question is whether this spot frequency has anything to do with terrestrial events. There is quite a school of astronomers who believe the sun spots are at the bottom of our terrestrial meteorology, so that if we watched the spots closely enough we could predict the character of the season. I do not think that is true; it is not borne out by facts. There is only one fully ascertained relation and that is seen by these dotted lines which give the record of the magnetic storms.



Wolf's Sun-spot Numbers.

The compass-needle varies in direction from hour to hour, and from day to day, and once in a while it will fly around several degrees in the course of a few hours and we call it a magnetic storm. Now it is beyond question that the magnetic storms upon the earth as observed simultaneously at various points upon the earth, have a precise parallel in the spottiness of the sun. There is a very important connection between the earth's magnetism and the solar surface; why it is I do not know.

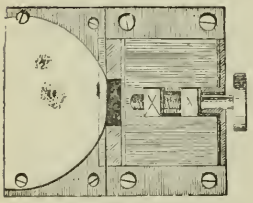


Distribution of Sun-spots and Protuberances.

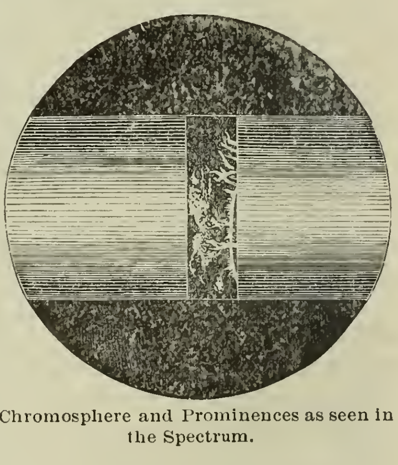
There is another thing about these spots; they are not distributed alike on the surface; they are found on what we might call the temperate regions of the sun's surface; that is to say, on each side of the sun's equator the sun-spots are most numerous. This diagram shows the distribution of fourteen hundred spots between the years 1861 and 1863.

We next pass to a different topic—the chromosphere and the solar prominences. Here is a photograph of the eclipse which occurred in 1869. It was taken so quickly that the corona does not appear, but only the solar prominences. These objects had been observed nearly one hundred years before, but no one knew what they were or where they were until 1860, when photography showed that they were things on the sun; that they were not lunar clouds, but actual appendages of the sun itself.

The next photograph shows how they were a minute later. The sun had passed on and its edge is just breaking out behind the moon, and you see that now we have the prominences on this side projecting much further than before. In the first picture all the lower part was covered; of course the second observation was enough to show that this object, thus progressively uncovered, was at the sun's surface; that thing must have been one hundred thousand miles long; it is known now to have been mainly a mass of hydrogen gas. The year before, in 1868, there was an eclipse in India, and all the different observers said that the prominences showed a spectrum of bright lines, although they did not all agree on other points. All but one or two agreed that they were lines of hydrogen gas. At this time Janssen, and a little later Lockyer, found that they could see the lines in full sunlight without waiting for an eclipse, and could also see the prominences (by the help of the spectroscope, of course).



Opened Slit of the Spectroscope.



Chromosphere and Prominences as seen in the Spectrum.

The figure represents the end of the collimator of the spectroscope and here is the slit upon which the image of the sun made by the telescope falls; the edge of the sun has just to touch the edge of the slit. By looking into the spectroscope you will see the spectrum of the sun as shown in this next diagram. I am supposing it is a very large spectroscope so that you get only a small portion at one time. The image of the slit corresponding to the *C* line, looks like a dark band across the spectrum. Here you have a rounded rim which is just the edge of the sun, and out of that project these prominences and clouds. You can look at them at your leisure, much as though standing at the back of the room you were looking out of your window at the clouds, nearly shutting the blinds so as to see through a rather narrow crack. If you open the slit too widely everything becomes indistinct, but if you make the opening narrow it becomes clear, and you can study the picture at your leisure.

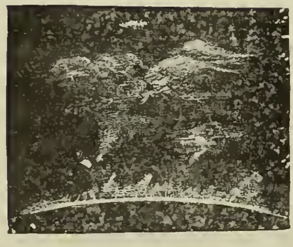
The whole surface of the sun is found to be surrounded by a rosy shell called the chromosphere. Through the photosphere rises the heated gas from below which streams out in filaments all over the sun's surface, and clothes it in a sort of fiery fur, while here and there great columns of flame arise. Sometimes they rise three hundred thousand miles above the sun's surface but not often; frequently as many at a time as you see there in this picture of Secchi's. Of course you cannot see all over the sun's surface at once, but you can hunt around the edge of the sun's disc and find in the course of half an hour all that there are there. These clouds vary almost as rapidly as the clouds upon the earth. Remembering how enormous they are, rising some sixty thousand miles high in the course of a few minutes, you can of course see that the motion must be tremendous.

Here are pictures of prominences observed at Harvard College in full sunlight. Here again is one of Lockyer's early observations, the two pictures being taken about ten minutes apart. Here are some of the forms which look like jets of liquid; I suppose they are jets of something thrown up through the hydrogen. I have not time to tell you why we could not see a jet of cast iron, while we could see a jet of hydrogen.

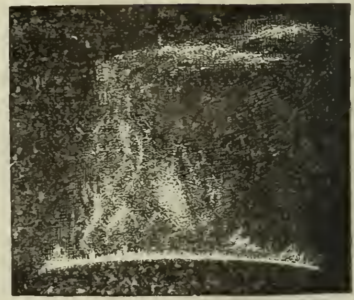
Here are formations I have observed myself. The upper one is particularly interesting since it bears on the queston frequently raised whether the sun has an atmosphere above the chromosphere; now once in a while a curious thing happens as shown in this picture. A cloud begins as a little speck and grows apparently without any connection with the sun below. Here is an example in the right hand of the diagram which shows a very rapid change. I saw this upper figure one day before going down to lunch and about forty minutes later when I came back the thing had actually blown up as shown in the picture below it. While watching it I saw some of the filaments moving visibly like the minute hand on a watch, and ascending until

QUIESCENT PROMINENCES.

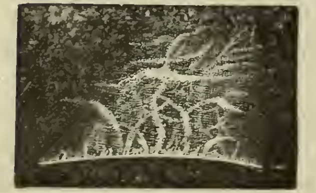
(Scale, 75,000 miles to the inch.)



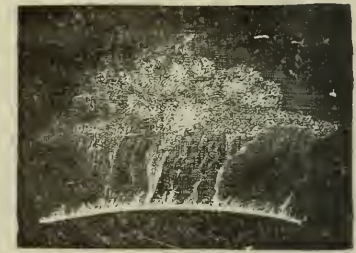
Clouds.



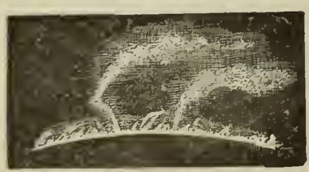
Diffuse.



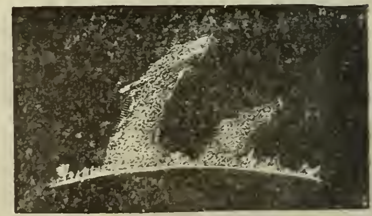
Filamentary.



Stemmed.



Plumes.

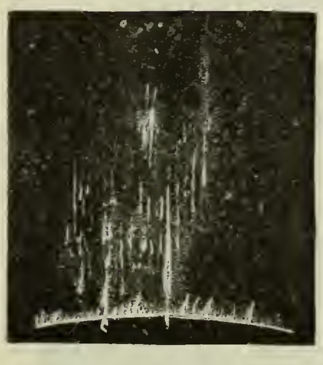


Horns.

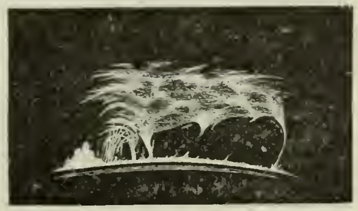
[NOTE.—Nearly all the engravings, illustrating Prof. Young's lecture, have been reproduced from his admirable volume entitled "The Sun," which forms Vol. xxxiv of the "International Scientific Series," published by Messrs. D. Appleton & Co., of New York. For the privilege of using these illustrations, the Committee on Publication is indebted to the politeness of the publishers.—THE COMMITTEE ON PUBLICATION.]

ERUPTIVE PROMINENCES.

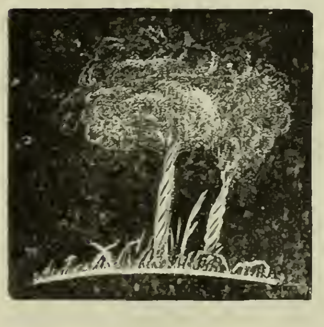
(Scale, 75,000 miles to the inch.)



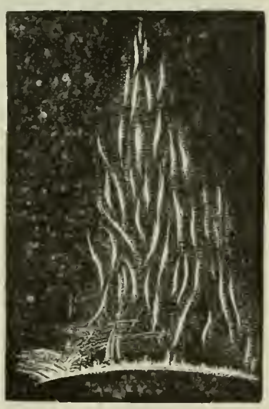
Vertical Filaments.



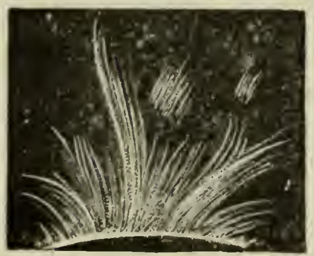
Prominence as it appeared at half-past twelve o'clock, September 7, 1871.



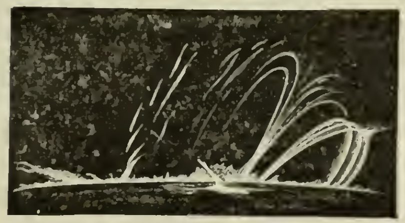
Cyclone.



As the above appeared half an hour later, when the up-rushing Hydrogen attained a height of more than 200,000 miles.

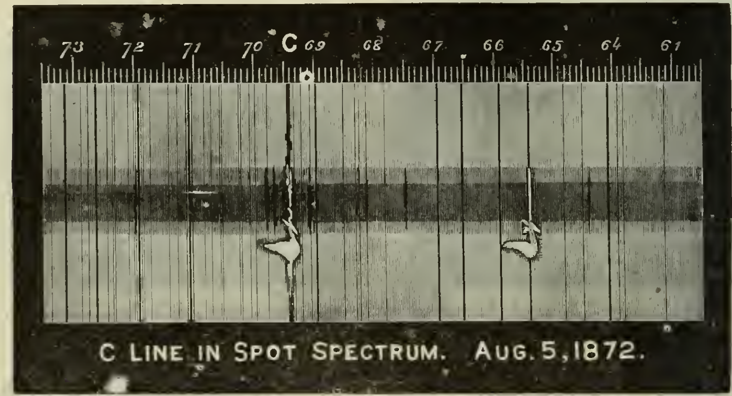


Flames.



Spot near the Sun's Limb, with accompanying Jets of Hydrogen, as seen October 5, 1871.

they vanished. They were going at the rate of two hundred miles a second. I think it is fair to call that explosive action. We cannot do anything as violent as that with explosions on the earth.



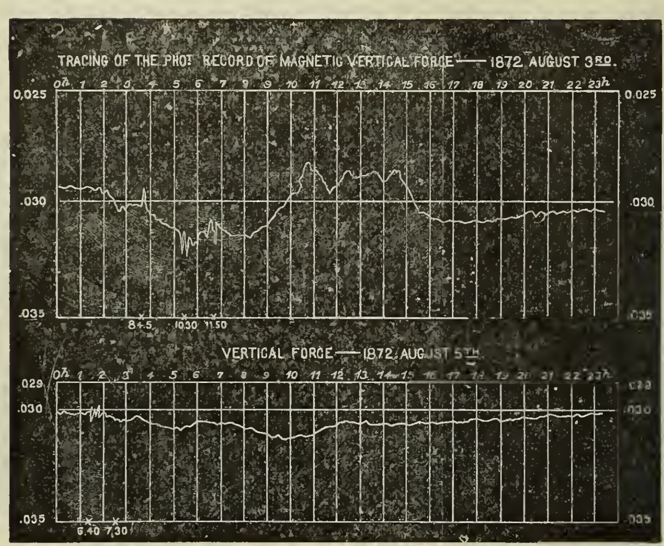
C LINE IN SPOT SPECTRUM. AUG. 5, 1872.

Sometimes in connection with these prominences and spots we have very curious effects on the spectrum. Here is a spectrum of a sun-spot observed in 1872; here is a dark line, the next is the *C* line of hydrogen, and here is a bright blow-pipe flame coming through it. The interesting point about it is that just at that very time there was a disturbance noticed at Greenwich and at Kew in their magnetic instruments. This diagram shows the behavior of the magnetic instruments at Greenwich. A day or two before there were great prominences there and they also showed curious things in their spectrum. Here in the upper figure is what was taking place at Greenwich: Three observations of disturbance in the prominences taken that morning were precisely simultaneous with those changes of the magnetic needle, and were thus connected with the magnetic disturbance. On the day the sun-spot appeared it was for the most part a very quiet day, magnetically speaking; but about 2 o'clock that afternoon (Greenwich time), for two hours the magnetic needle had the fever and ague; now that was the time the sun-spot was throwing out a gaseous flame, as observed by me in America. That is one marked instance showing the simultaneousness of these phenomena; and there are about a dozen such instances on record.

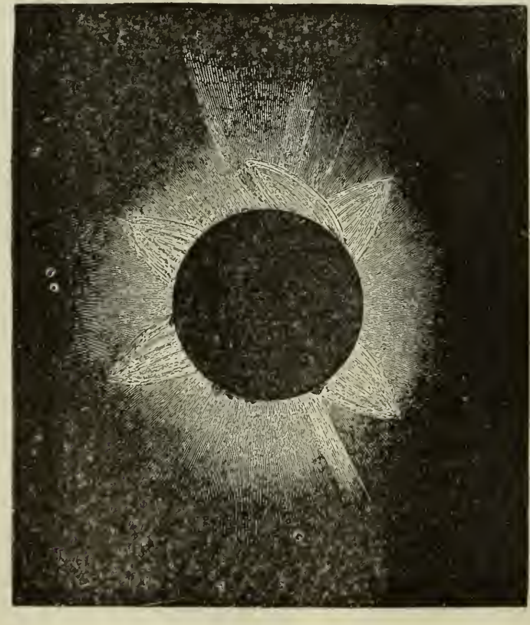
At the time of a total eclipse we see not only these prominences but the sun is surrounded by a peculiar halo or glow. This is a most impressive sight; you have the moon black and round, and reaching out from it in all directions you have these silver rays from the sun fading out at a little distance. This figure represents it as it appeared to the French astronomer, Liais, in 1857. The peculiarity is this petal-like formation which was observed in the corona at that time.

Here is a picture that Gilman made of the corona in 1869. All the observers saw that inner portion, that irregular quadrangle, but I do not think the most of us saw those dark rays reaching out from the sun. Now what is that corona? If it is really something at the sun it must be enormous. The sun itself is eight hundred thousand miles in diameter; if this is an atmosphere around the sun it is of an enormous extent. Just at present astronomers are greatly at variance with each other as to the true theory of the corona; most of us think it is a real solar phenomenon, but there may be some optical illusion connected with it. One of our distinguished American astronomers thinks it is only an apparition, that it is mainly the effect of diffraction at the edge of the moon. The so-called corona line proves that to some extent it is a solar atmosphere or gas, but as to the main phenomenon the question is whether it is a mere optical apparition or a real halo actually enveloping the sun. I am disposed to hold the old view and think that it is a halo, and no mere optical effect.

This picture is a picture of what was observed in South Africa in 1875, and this is a photograph of the corona in 1869, taken at the same time with Gilman's picture. It however shows none of his dark rays; the best photograph ever made of the corona I now throw upon the screen, and that as you see came to grief some time ago by the breaking of the plate. It was made at Baikul, in India, in 1871; it was a very beautiful picture indeed in the original condition. You can see how far these streamers reach from the sun; the existence of the halo is almost demonstrated by the photographs made during this eclipse, because another picture of the same eclipse made in Java several hundred miles away, and several minutes later agrees with this even in minute details. Six photographs were made at Baikul at that time, and by putting them together this picture was constructed. I call your attention to one thing especially. You notice up here a curve which is convex towards the sun; if that is a real substance it amounts to a demonstration that there are repulsive forces in the sun; otherwise you could not get a curve convex to the solar surface. But all the phe-

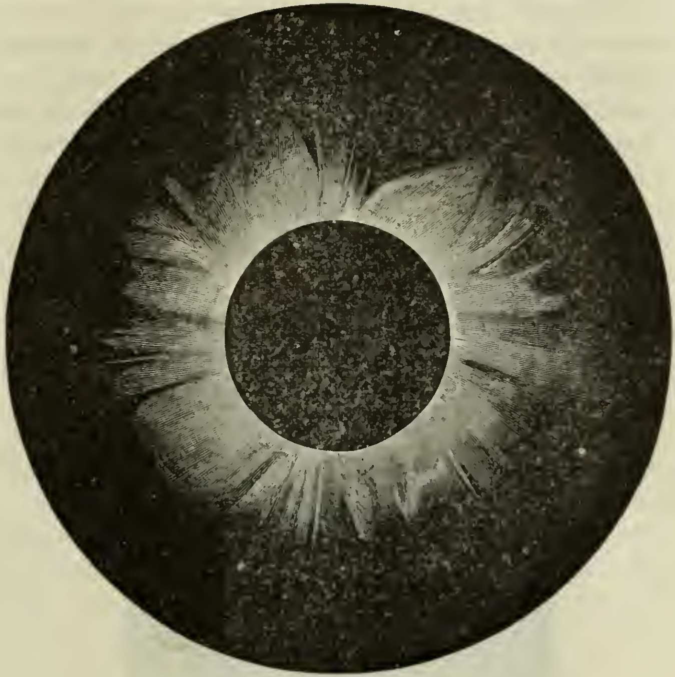


Magnetic Curves at Greenwich, (August 3 and 5, 1872.)



Corona as observed by Liais in 1857.

nomena of comets' tails shows that in some cases the sun exercises repulsive force upon matter.

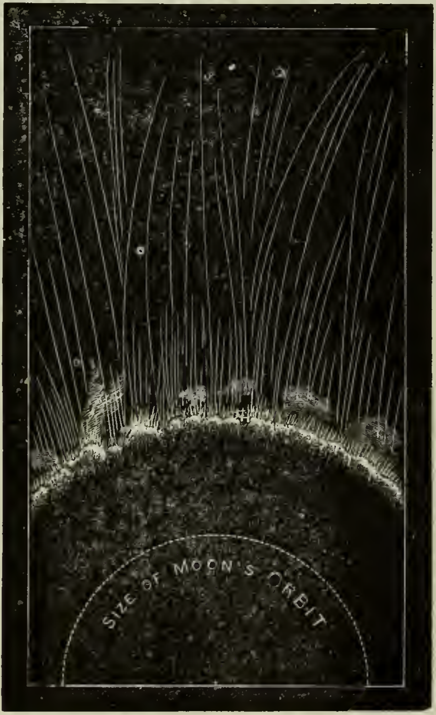


Corona of 1851. (Davis.)

This next corona picture is a picture taken of the eclipse of 1878. You see it gives even a more extensive corona than is shown by the pictures of Lord Crawford's party; but it also illustrates the difference between dry and wet photographic plates in the amount of detail. The outer portion is as clear as any picture ever made, but the inner portions have lost all their detail.

In closing, I show you a diagram that I hope will leave you with a clear idea of the structure of the sun. I will not detain you by any hypotheses of how the solar heat is obtained; it is a matter about which we do not absolutely know anything. The idea is that it is a slow contraction of the whole mass of the sun; but the only difficulty with this is that it limits the duration of the process to a few million years, it only gives us fifty or one hundred million years for the whole life of the sun.

To recapitulate; first we have within, an unknown nucleus of gaseous matter heated intensely, in a state of vapor under high pressure, but still gas, although it is denser than water. If we were to try to move about in it, it would resist our movements very much as if were to try to wade through tar and pitch. In this diagram if this represents the sun, that dot would be about the right size for the earth, and this circle the right size for the moon's orbit. Next we have the shell of clouds that covers the whole and constitutes the surface of the sun. The cavities here, and at other places would be sun-spots. As to the thickness of this envelope nobody knows anything; It may be fifty thousand miles thick, or not more than five thousand. Though it continually rushes up the gas from below, these clouds of course are heavier than the gas upon which they rest, and so must settle down like rain clouds. They descend continually and force up other materials from beneath, and this up-rushing gas constitutes the chromosphere represented by this row of flames. That sheet of what we may call flames



Ideal Section—Showing Constitution of the Sun.

constitutes the chromosphere, and above that are the prominences or clouds. Above all is that serene corona whose nature is still a mystery to us.

We see how much remains to be learned; we do not know what the corona is; we do not know how the spots are formed; we do not know about the atmosphere of the sun. The road is open for future discoveries, and that is all I dare say about it.

SYNCHRONISM*

By Prof. Edwin J. Houston.

Among the many practical problems whose solution has long been sought for, but sought for in vain, until very recently, is the problem of obtaining approximately absolute synchronism.

A pendulum completes its to-and-fro motion, or oscillation in a given time, that is, independent of the distance through which it swings, or, in other words, independent of the amplitude of its oscillation. The time required to make one complete oscillation being exactly the same as that required to make any subsequent oscillation. This fact is expressed when we say, that the oscillations of a pendulum are isochronous.

When we include the idea of any one event happening in exactly the same time as that required for another event to happen, we express this fact correctly by saying that the movements of the two are synchronous. That is to say, the two not only start together, but complete all parts of their motions in the same time.

In order to render the preceding clearer, let us suppose that two tuning forks be started in vibration. Either fork will continue to make isochronous vibrations, if the time required by such fork to complete any single vibration is the same as that required to complete any subsequent vibration. While the vibrations of either fork may be isochronous, it does not follow that the vibrations of the two forks are synchronous.

Either of the two forks may be isochronous in its motions, although one of the forks may make 256 vibrations per second, while the other makes 512 vibrations per second. Either of the forks is isochronous, because it requires the same interval of time to complete any single to-and-fro motion; but the two forks are not synchronous, since one of them makes 256 vibrations per second, while the other makes 512 vibrations. In order that they may be synchronous they must each make the same number of vibrations in the same time.

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* A paper read before the American Institute of Electrical Engineers, at Philadelphia, October 1884; with discussion thereon.

The modern idea of synchronism includes the additional notion that the two bodies must not only move through the same distance in the same time, but also that their motions during the entire time must be exactly similar, that is to say, that they must be synchronous at all points during their movements.

Let us suppose, for example, that two pendulums be started at exactly the same time and be permitted to swing for, say, one minute. It does not at all follow that because they make the same number of oscillations during that time that their oscillations have been necessarily synchronous throughout the entire time of their movements, that is throughout the entire minute; since, in accordance with the definition of synchronism we have above given, it is not only necessary that the two bodies shall have moved through an equal distance, or, in other words, shall have started and stopped at the same time, but that they shall have been synchronous in their movements throughout all parts of the entire number of vibrations made.

Many attempts have been made to attain synchronism, but up to within comparatively recent date, it would seem that these attempts have been unsuccessful in obtaining the synchronism to which reference have just been made; that is the synchronous movement, for an indefinite period of time, of free moving bodies mechanically independent. For example, a ratchet wheel and cog-wheel, controlled by pawls, star wheels, friction or other mechanical devices, may be approximately synchronous in their movements, but with such movements I do not propose to treat, since they could not well be otherwise than approximately synchronous, and are not involved in a proper understanding of the term.

For example, the House Printing Telegraph, Hughes' Printing Telegraph, Calahan's Stock Printing Telegraph, Edison's Chemical Stock Printing Telegraph, Meyer's Multiplex Telegraph, Baudot's System of Telegraphy, Casselli's and Bonnelli's Autographic or Fac-Simile Telegraph, and Edison's Autographic Telegraph, are all operated by mechanically synchronized movements, which are brought into unison at given times by certain mechanical devices electrically controlled, which bring them to a full or partial stop by certain mechanical impediments, frictional or otherwise, to their free motion, and these corrections being in all cases pre-arranged, are made use of whether the movement of the machine requires them or not.

Such movements, however, are not comprised in the idea of synchronism as it has been above defined, nor are they worthy the designation of synchronous movements, since their movements are never free or independent of mechanical appliances. They merely afford instances where different apparatus are maintained in a somewhat approximate synchronism for a very brief interval, when they are stopped, brought into unison and again started.

A considerable stride in the direction of true synchronism was made by Prof. Paul La Cour, of Copenhagen, whose genius has created the phonic wheel, a contrivance by means of which a rapidly interrupted circuit in an electro-magnet keeps in even rotation an armature wheel the impulses of the magnet being made effective by increments so fine on the armature wheel, that a uniform movement, hardly attainable by any other known device, is produced.

In strong contrast with the previously mentioned efforts towards synchronism, we have to-day the practically perfect synchronism of Mr. Delany, who, with marvellous ingenuity, has succeeded in obtaining and maintaining synchronism in the highest and best sense of the term.

I will be better understood when I call your attention to the fact that he has succeeded in keeping two bodies, separated by hundreds of miles, in synchronous rotation for periods of upward of seventy hours, without variation during that time of the $\frac{1}{1000}$ part of a second. This is equivalent to two entirely independent bodies separated from each other by hundreds of miles, starting together and passing through a distance of nearly one hundred miles without varying the $\frac{1}{100}$ part of an inch in that entire distance, or the $\frac{1}{1000}$ part of a second during that entire time.

The period of seventy hours I have mentioned, has no significance, so far as the limit of time is concerned, since these movements can be maintained for weeks, or months, or even for an indefinite period, with a like degree of accuracy; it being only necessary to keep the voltaic batteries, used in this system in working order.

Mr. Delany has chosen for his system the phonic wheel of La Cour as affording the movement the best suited for regulation by his synchronizing device.

I will pass over the results he has already obtained in the shape of multiplex telegraphy, which, as you are probably aware, has been in successful practical operation under his system for some months past. In this system, circuits ranging in number from six to seventy-two, according to their capacity, have been obtained over a single wire, admitting of the transmission of from six, to seventy-two separate messages, at practically the same time, either all in one direction, or any portion of the whole number in opposite directions. These circuits so obtained may be adapted to the Morse system or to the printing system, the Morse system being applicable up to twelve circuits at the ordinary rates of transmission ; the speed of any number of circuits being dependent on the number of connections that any particular instrument gets with the line in a given time.

The operation of the Morse system by the Synchronous method involves a feature that has probably never been explained, and to it I will therefore call your particular attention. If we consider that for one complete rotation of the synchronized distributor, which constitutes one end of the line, the line passes over 72 contacts, which may be used for the transmission of messages, and, that under the sextuplex organization, each of the six operators' instruments would be connected to twelve of these contacts in the circle, and that the distributor rotates at the rate of $2\frac{5}{6}$ times per second, we will find that each of the six operator's instruments would be connected to the lines 12 times for each complete rotation, or 34 times per second, and that all these operators have been put in connection with the line, and with their correspondents at the distant ends, through the synchronized distributor at that point, 34 times in a second. Now while one operator is making the shortest character or letter in the Morse alphabet, which is the letter *e*, consisting as it does of a single dot, let us see what takes place while this single dot is being transmitted. Let us imagine that when the first operator touches his key, and depresses it for the shortest interval of time that he is capable of holding it depressed, the distributor with its trailing finger, which is the end of the line, passes over one of the 12 segments connected to this operator's instrument, and transmits to the other end a portion of this single dot, but does not complete it until the other five operators have been placed in connection with the line, and the second, or third segment of the first operator's circuit has been touched by the trailing finger when the single dot representing the letter *e* is completed. Thus one dot is made up of two, three, or more shorter impulses, which manifest themselves on the polarized relay at the distant end, as one short signal, notwithstanding that portions of letters or characters have been transmitted by five other operators between the time of the beginning and the completion of this single dot. This is an irrefutable evidence of a synchronism that has never before been more than contemplated as but a remote possibility.

The operation of the printing instrument by this system is another illustration of the degree of perfection of Mr. Delany's synchronism, that is hardly less striking than the foregoing; since if seventy-two printing instruments are used, each instrument must be dependent on a single segment for its messages, and an instrument at each end of the line being connected to a single segment correspondingly located, the distributor must connect the line with those single segments at precisely the same instant, otherwise no impulse for the indication of a letter on the type wheel will be received. Theoretically it might be supposed that the transmission of a signal, say from Philadelphia to New York, by an instrument connected to a single segment would not necessarily require that the trailing finger in the New York instrument should be on the corresponding single segment at the time that the signal was sent into the line at the Philadelphia end. Or, that the trailing finger on the New York instrument might be one segment behind the segment corresponding to the segment on which the signal was sent into the line at Philadelphia, and that still that the signal could be received on the corresponding segment in the New York instrument, since the time required for that signal to pass and manifest itself in New York would be sufficient to allow the New York instrument to reach the segment corresponding to the one from which the signal was sent into the line from Philadelphia. The fact that it takes time for the transmission of signals according to the distance and other conditions not necessary to discuss here, no one will dispute, but, that this time admits of variation of movement or departure from synchronism in Mr. Delany's machine, is disproved by the machines themselves; for, if another instrument be connected to the next adjoining single segment in each machine, and a signal be sent from New York to Philadelphia immediately after, or within about the $\frac{1}{500}$ part of a second afterward, the signal from New York is received in Philadelphia as perfectly as that from Philadelphia was received in New York thus, showing conclusively that the conditions of variation before referred to could not have existed, since otherwise no signals could be received from New York or Philadelphia, over the second segment, as the Philadelphia instruments would have left the segment before the signal could have been completed on the segment in the New York machine and transmitted to Philadelphia.

Probably the most extraordinary proof of practically absolute synchronism was demonstrated by the experiment recently made by Mr. Delany over the line between Boston and Providence, whereby a single dot was transmitted from Boston to Providence and automatically repeated back and forth over the same wire at practically the same instant of time, travelling over different circuits in rotation backward and forward for the duration of five minutes, during which time it traveled four hundred and fifty thousand miles, this time, of course, being almost wholly represented by the movement of the armatures of the instruments. When we consider, however, the conditions involved in the transmission of a single dot, as in the case of the letter *e*, already referred to, the extent of perfection of the synchronism obtained will be understood.

Before concluding, I desire to call your attention to some contemplated applications of the wonderfully complete synchronism of Mr. Delany which he has conveyed to me. Among some of these may be mentioned fac-simile transmission, or the reproduction of signs, characters, or hieroglyphics. For instance, a fac-simile copy of a dispatch, or drawing of a map, or a pen portrait of an individual may be transmitted to any distant point. The prime condition necessary being synchronism, the time is probably not far distant when the civil authorities can render the identification of criminals almost certain by having their portraits in the hands of an officer on the arrival of the train upon which the criminal has fled. Or, a newspaper in these days of enterprising journalism, many have transmitted for publication a sketch of a great public disaster, or of any other event calling for illustration.

In conclusion, permit me to say that the invention by Mr. Delany of practically complete synchronism would appear to go no little way towards the solution of a problem that stares practical men so squarely in the face. I allude to the problem as to what shall be done with the electric conductors, that are strung over the houses, and through the streets of our large cities. Whether these wires are to be placed underground or are to continue overhead, is a problem which in my opinion is as yet far from being solved. The increased capacity which Mr. Delany has obtained for every wire will, it is clear, greatly decrease the number of wires required for actual use, and this makes the problem referred to somewhat easier of solution.

DISCUSSION.

Prof. Houston:—I would say here, however, that Mr. Delany's system is not necessarily dependent upon the phonic wheel, as he has invented an electro-magnetic motor which, when placed in connection with his automatic system of control, is capable of and containing exactly similar effects as are obtained with La Cour's phonic wheel.

Mr. Delany has very recently made an experiment on the telegraph lines of the Pennsylvania Railroad, and has sent messages from Philadelphia to New York and back again to Philadelphia. That was done last Sunday. I do not know how many relays were worked, but the system worked successfully on the Pennsylvania lines.

In concluding this paper, I may mention, that I have had some conversation with Mr. Keith as to whether or not it would be advisable to go into a discussion of the means by which Mr. Delany has obtained his synchronism, and we came to the conclusion, that the time available to us is so short, that it would not be worth while to go over the description of the means, which we can fairly suppose the members are familiar with. Mr. Keith tells me, that when he publishes this paper, he will probably reprint some of the articles that I have written, which contain a full and exact description of the methods employed. Otherwise it would be difficult to compress any description of the system into the space of an hour. I see, very fortunately, that Mr. Delany is here himself, and if there is time, I would suggest, that he be called upon.

The Chairman (Mr. W. D. Sargent):—Mr. Houston has given us a very interesting paper. As I understand, Mr. Delany is here, and our time is limited—but we would be glad to hear from Mr. Delany.

Mr. Delany:—I don't know that I have anything to say, unless some persons, not understanding the theory and principle of synchronism, would like to make inquiries, if so, I would be very glad to respond.

So far as an explanation of the system is concerned, I think it would be much more satisfactory, individually and collectively, if we would go to the exhibition and see the system in operation. There every facility is at hand to make a much clearer explanation as to how it is done, and that certainly would be much more satisfactory than anything I would attempt to do here. However, if any of the gentlemen have anything to inquire about, I would be very glad to enlighten them as far as I can. I take pleasure in extending to the gentlemen of the conference here a cordial invitation to come out and see our system in operation in the exhibition building. We will be there during the week, and when they come, if they will make themselves known, I shall take particular pains to show it to them.

The CHAIRMAN:—Your apparatus in that building is simply working in the building?

Mr. DELANY:—We have no outside facilities at all. On Sunday we worked, from Philadelphia to Jersey City and back, over the Pennsylvania wires with a No. 9, and a No. 8, wire. One was an old wire, I don't know its electrical condition, it seemed to be in pretty good order.

Mr. MAILLOUX:—You are working through an artificial resistance, are you not?

Mr. DELANY:—Yes, our battery is very limited, consequently we are restricted to a lower resistance. On Sunday we had the Pennsylvania Railroad batteries, so we were able to work through to New York and return.

Mr KINTNER:—What is the longest circuit you have worked?

Mr. DELANY:—We worked a year ago over the American Rapid Line from Boston to New York. We had then only progressed as far as the quadruplex.

Mr. KINTNER:—Do you find any static trouble over that distance?

Mr. DELANY:—There we had static trouble, but it was overcome.

Mr. KINTNER:—By ground contacts?

Mr. DELANY:—Ground contacts. This was entirely practical. The ground contacts afforded us a mechanical remedy for getting rid of the static troubles within our reach. For a longer distance, it would only be necessary to make the ground contacts a little larger.

Mr. KINTNER:—I was thinking of that.

Mr. DELANY:—Or larger than the contact connected with the operators' instruments. Of course such an enlargement would to a certain extent be at the expense of the operator's contact. If we have ground contact about the same size, so the line will have the same duration with the ground that it had with the operator's instrument we can work very satisfactorily. The circuit referred to was 250 miles, over a No. 8, galvanized iron wire. If it is necessary to work further over that kind of a wire, we will probably have to put in repeaters or use a copper wire.

Mr. KINTNER:—Have you ever tried the condenser?

Mr. DELANY:—We could not use that very well; we could not apply the condenser, because our currents are constantly being reversed. We use polarized relays. So while it would assist in one instance, it would create a difficulty in the other.

Mr. KINTNER:—I had forgotten about the polarization.

Mr. DELANY:—We have worked successfully through three repeaters, and have worked through five; it was simply only necessary that the sounder of one circuit should become the transmitter in another circuit.

The CHAIRMAN:—To what extent is your system dependent upon the electrical condition of the conductor between the two ends?

Mr. DELANY:—We have but very little difficulty from that cause. Synchronism is maintained, if we get sufficient current over the line to actuate the armature of the correcting relay, adjusted in the most sensitive way, the armature of the electro-magnet is adjusted by a delicate spring, so as to keep the armature against the back stop. If we get a sufficient current over the line to move the armature from the back stop, we can synchronize. In fact we can synchronize further than we can telegraph. Any ordinary change in the condition of the line does not affect us at all, because frequently we have put three or four thousand ohms of resistance into the line, and taken it out suddenly without affecting our synchronizing apparatus. With polarized relays and reversed current, a fluctuating condition of the line does not affect us as it would an ordinary relay. It is simply a question whether you get sufficient current over the line to actuate the most sensitively adjusted relay. As long as we can do that we can work.

Mr. MAYNARD:—Is it possible for these machines to get out of synchronism?

Mr. DELANY:—Oh, yes.

Mr. MAYNARD:—What do you do then?

Mr. DELANY:—They come in of themselves, if you let them alone within two minutes. The correcting impulses sent over the line will correct a discrepancy in vibration of the forks of about five vibrations per second. If you should open a wire between the two stations, the instrument would then have to run independently, they would get out of synchronism within a minute or two. The instrument may be locked up and not be accessible to anybody. If they should be thrown out of synchronism they would come to that point again of themselves.

Mr. MAILLOUX:—Do you maintain the line of circuit so they can keep themselves in a synchronal condition?

Mr. DELANY:—Oh, yes; the line of circuit is always closed, subject, of course, to interruptions of the commutator from the circuit table.

Mr. MAILLOUX:—I mean when the operator wishes to send a message in the ordinary way, he does not have to wait until the line is synchronized.

Mr. DELANY:—He has to wait until the line is synchronized to send the message; if he did not, the message would not reach the operators in connection with that circuit at the distant end.

Mr. MAILLOUX:—When the machine is in use on the line, I wish to inquire whether the machine is maintained in a synchronized condition?

Mr. DELANY:—It is always maintained in a synchronized condition. Each operator's instrument is always to the ground, so that if the operator at the other end of the line closes his key, it is manifested directly to the corresponding operator at the distant end.

Mr. MAILLOUX:—It is your purpose, is it not, to maintain that local circuit in action all the time, so that the phonic wheel is moving all the time at either end?

Mr. DELANY:—Always; at night we shut them down if there is no longer necessity for running them.

Mr. MAILLOUX:—You open in the morning and synchronize?

Mr. DELANY:—After we start them in the morning they run all day.

Mr. MAILLOUX:—With the ordinary Morse system how many transmissions can be made practically and profitably over one wire?

Mr. DELANY:—We make six transmissions by the Morse at the highest rate of the ability of the operator. That is, you can send forty words per minute—we have transmitted from Providence to Boston, and Boston to Providence and back to Boston by a line, which I suppose is a circuit of about 100 miles, very close to 1,000 words on the sixth of a wire, *i. e.*, when the wire was distributed sextuplex, at the rate of from 43 to 44 words per minute. I received myself over a twelfth of a wire, eleven hundred words, at an average of twenty words and a fraction. It is equal to 18 or 20 words beyond a doubt.

Now as to the commercial advantages of either the six, or twelve divisions of the segments, that is a question. For commercial telegraphy I suppose that between two offices doing an ordinary telegraph business, the six circuits could be worked to the best advantage, because it requires the less number of operators to the circuit, and each circuit is equal to the best ability of the most expert operator. But for renting purposes, you may rent twelve circuits to a greater advantage than the six ; beyond the twelve we have to abandon the Morse system and use 'Printers.'

WATERPROOF CEMENT FOR PAPER.—Labels can be attached to tin-boxes, or to other metallic surfaces which are exposed to dampness, in the following manner: Dilute white of egg in an equal quantity of water, or dissolve dry commercial albumen in two or three times its weight of water and apply the liquid with a brush upon the two surfaces which are to be joined. Iron the surface with a hot smoothing iron. By joining successive layers of paper in this manner, paper boxes may be made, which will be waterproof.—*Jour. d' Horlogerie ; Les Mondes*, April 12, 1884. C.

A MINING PROBLEM.—The *Bulletin des mines* records the explosion of a heavy blast of dynamite which produced but little effect. The failure was attributed either to an insufficient charge, on account of the exceptional hardness of the rock, or to a crevice by which a large portion of the gases had escaped. Neither of these reasons, however, was the true one. One of the two halves of the original charge had remained unexploded in the rock, and it went off, some days afterwards, at the moment when several other blasts were exploded in the neighborhood. Fortunately no one was injured, but the consequences might have been very serious if the explosion had occurred while the miners were in the quarry. It is obviously an important problem to determine how best to ascertain whether all the charges of a blast have been really exploded.—*L'Electricien*, June 1, 1884. C.

MOTION OF THE SUN.—It has been hitherto supposed that the solar system is moving towards the constellation Hercules; but the investigations of Prof. Plummer, of Oxford, lead him to believe that the point towards which we are moving is nearer the constellation Lyra than has been generally suspected. As it is not likely that the sun describes a straight line in space, it becomes important to collect all possible information which may help us to ascertain the exact form of its orbit.—*La Nature*, May 31, 1884. C.

AN EXPERIMENT IN WEATHER FORECAST.

By Pliny Earle Chase, LL.D.

[Read before the American Philosophical Society, January 16, 1885.]

The class of '88, in Haverford College, have studied Chase's Elements of Meteorology, with a special view to the formation of trained habits of observation. They have acquired such skill in local weather forecast* that they undertook, early in December, to predict the probable regions of fair and stormy weather for all parts of the United States, on Christmas and New Year's days. The predictions were forwarded to Washington and submitted, through the courtesy of Gen. W. B. Hazen, Chief Signal Officer U. S. A., to the Board of Indications, to ascertain the degree of accuracy.

The following were the grounds of forecast:

1. The mechanical influence of solar and lunar tides on atmospheric currents, which has been tested by sixteen years' investigation and observations at Philadelphia and Haverford College. The normal tendency of tidal pressure, independent of friction, polar and equatorial currents and other disturbing influences, is from the East at syzygy; from the South at the following octant; from the West at quadrature; and from the North at the following octant: thus forming a lunar wind-rose, of a like character to Dove's solar wind-rose.

2. The normal percentage of average lunar rainfall on the several days of the lunar month, as deduced from three years' observations of the Signal Service Sergeants (Proc. Amer. Phil. Soc., xiv, 416–8).

3. The Signal Service tables of the winds which are most likely, as well as of those which are least likely, to be followed by rain or snow in each region, during each month of the year.

I had previously stated (Elements of Meteorology, Part i, p. 95), that "a verification of lunar forecasts in five cases out of nine should be regarded as satisfactory. In favorable localities, if due regard is paid to temporary local influences, predictions may often be made for a month in advance, which will prove true in three cases out of four." The reports which were received from the Signal Office were examined in several different ways, the lowest mean verification of lunar influence for the two days being 59 per cent., while the highest was 100 per cent., as is shown by the followings tests:

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* The verifications, after two months' study, ranged between 74 and 90·3 per cent., the general average being 81·5 per cent.

I. TESTS OF LUNAR INFLUENCE.

α. The tri-daily bulletins of the Signal Service Bureau, show that in 13 of the 22 regions, or 59·1 per cent., there were such differences of barometric pressure between the two days of observation as should be produced by tidal influence, viz., increased pressure when the normal currents are retarded, diminished pressure when they are accelerated.

β. The normal relation of temperature to pressure (thermometer rising when barometer falls, and *vice versa*) was shown in 17 of the 22 regions, or 77 per cent.

γ. The tendency to partial reversal of surface currents by friction, in passing over the land, and consequent partial opposition of lunar influence,* was shown in 19 of the 22 regions, or 86 per cent.

δ. The rainfall on Christmas day was 1·07 times as great as that upon New Year's day. The lunar normal ratio was 1·04. This represents a verification of 97 per cent.

ε. The influence of "favorable localities," independent of any regard to "temporary local influences," was shown in the Middle Atlantic States, where the verification was 100 per cent., the weather at every station, on each of the days, being such as was foretold.

II. TESTS OF SOLAR INFLUENCE.

ζ. The special report of the Board of Indications, showed a verification of 70·7 per cent. for the fair forecasts; and a rainfall, in amounts sufficient to be measured, in 25 per cent. of the regions for which stormy indications were foretold. The full significance of this test cannot be satisfactorily determined, because the normal proportion of stormy winds which bring actual rainfall has never been published.

η. The forecasts which were authorized by the Signal Service tables showed a verification of 1,275 ÷ 19 = 67·1 per cent. on Christmas day, and of 575 ÷ 15 = 38·5 per cent. on New Year's day, or a general mean of 1,850 ÷ 34 = 54·4 per cent. In three of the regions at the former date, and in seven at the latter, no forecasts were prescribed by the tables, the wind-deflecting tendencies being from doubtful azimuths. This test, like the foregoing, is affected by the uncertainty as to what constitutes a satisfactory verification of storm-forecasts which cover winds from one-half of the azimuths.

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* Elements of Meteorol. Part i, pp. 93–5, Par. 1, 8; Proc. Amer. Phil. Soc. xi, 113.

θ. As nearly as could be ascertained from the tri-daily reports, the stormy indications in the Signal Service tables were verified in 65 per cent. for the fair winds, and there was measurable precipitation after 43 per cent. of the stormy winds, the general mean verification being 60 per cent. This would indicate a verification, according to the preceding test, of 54.4 ÷ 60 = 90.7 per cent.

ι. The ratio of lunar to solar monsoon influence, which was shown in tests *α* and *η* (59·1 ÷ 54·4 = 1.086) agrees very nearly with the ratio which was shown by the winds at Haverford during the past year (545 ÷ 514 = 1.06). Of 1,059 observations, 545 were nearer the azimuth which represented the lunar tidal tendency and 514 nearer that which represented the solar monsoon influence, as given by Coffin (Winds of the Globe, p. 431). This degree of accordance seems to justify the belief that the subsidiary value of lunar normals would be found as great elsewhere as it is at Haverford, for detecting and coordinating the abnormal influences of equatorial or polar, cyclonic or anticyclonic, local or general currents.

III. TESTS AT HAVERFORD COLLEGE FOR 1884.

κ. Tidal acceleration of atmospheric currents was accompanied by low barometer; tidal retardation by high barometer.

λ. The percentage, both of stormy winds and of cloudiness, was greater in the lunar stormy cycles than in the fair cycles.

μ. Of the 120 days on which the lunar tidal tendencies were more stormy than fair, 54 were accompanied by measurable precipitation; on 32 other days there were winds from stormy directions; 11 others were cloudy, and on 23 days no special evidence of stormy disturbance was recorded. This represents 81 per cent. of verification by storm or stormy tendency, and 19 per cent. of failure.

ν. Of the 120 days on which the lunar tidal tendencies were more fair than stormy, 74 were fair; on 21 other days there were winds from fair directions, and on 25 days there was rain or snow with no special record of fair influence. This represents 62 per cent. of complete verification, 17 per cent. of partial verification, and 21 per cent. of failure.

ξ. Making allowance for one day's possible shifting of fair and stormy tendencies, by the acceleration of equatorial cyclonic currents, or the retardation of polar anticyclonic currents, 85 per cent. of the fair, 71 per cent. of the stormy, and 79 per cent. of all the indications were completely verified. In this test no stormy verification was admitted in which there was not an actual measurable amount of rain or snow.

o. Of the winds from stormy quarters during the year, 63 per cent. were followed within 24 hours by measurable amounts of rain or snow. Of the winds from fair quarters, 72 per cent. were followed by fair weather for 24 hours, with no measurable amount of rain or snow. The mean verification of all the wind indications was 68 per cent.

π. The comparative value of forecasts, from lunar indications which might have been foretold years in advance, and from wind indications which are good only for a day in advance, was $45 \div 63 = 71{\cdot}4$ per cent. for storm; $62 \div 72 = 86{\cdot}1$ per cent. for fair; $53 \div 68 = 77.9$ per cent. for all.

ρ. The percentage of verification for stormy indications was greatest in winter and least in summer.

σ. The percentage of verification for fair indications was greatest in autumn, and least in winter. There were marked indications, however, of a tendency toward general maximum verification in summer.

τ. The percentage of total verification was greatest in winter, when the thermal disturbance of Moon's tidal action is least, and least in summer, when the thermal disturbance is greatest.

υ. The percentage of verification, both for the fair and for the stormy indications, was greater in the equinoctial semester than in the solstitial.

φ. The conflict of solar daily and monsoon influences with lunar monthly tidal influences was shown in numerous cases of stormy anticyclonism and fair cyclonism which had been overlooked in the daily forecasts from Washington. Predominating solar influence accounted for 32 of the 46 abnormal days during the fair lunar tendencies, and 51 of the 66 abnormal days during the stormy lunar tendencies, or 74 per cent of the whole.

It would be unwise to draw any positive conclusions from the results of a single experiment, or from observations for a single year at a single station, but there is certainly encouragement for continuing the line of investigation which is here indicated.

ELECTRICITY IN MEDICINE.

By Harrison Allen, M. D.

[Abstracts from a lecture on the subject of "Electricity in Medicine," delivered at the International Electrical Exhibition, Tuesday evening, September 30, 1884.]

[The lecture, as originally delivered before the International Electrical Exhibition, included a general resumé of the applications of electricity to the study of the phenomena of life, and especially to the practice of medicine. Of necessity a subject so comprehensive when arranged in a manner suitable for a popular occasion admitted of no expression of individual views, and indeed was so treated as to give to the auditor a general idea of the importance of electricity as an aid to physiology and to therapeutics, rather than to elaborate a single theme of interest to the investigator. After reverting to the phenomena of electrical animals, the lecturer passed to the observations of Franklin on the constant current upon the living body. An account of the researches of Galvani and Volta followed, and a succinct description was presented of the uses of these varieties of electricity in medicine as contrasted with that of faradism. The applications of the incandescent wire as a cautery as well as a means of illumination of the throat-passages ensued. Examples were given of the methods of Duchenne in studying the functions of muscles by determining isolated contractions of separate muscles by the induced current as well as the method referred to Reichenbach as a means of ascertaining the effects of a powerful current of electricity) which was caused to be passed through a powerful stationary magnet) upon the sense of sight. The method last-named was held by the lecturer to have special interest at this time, since the organizations of societies devoted to psychical research would probably lead to the repetition of the Baron von Reichenbach's experiments in this country.

In selecting from this extensive range of subjects one theme which would bear elaboration, the author has concluded that an exposition of that form of electricity in the application of which he is personally the most interested, would afford the best opportunity of presenting observations which might claim to be original, namely, in the use of the galvano-cautery as an agent in the treatment of diseases of the nasal chambers.—H. A.]

Ladies and Gentlemen: I desire to bring to your attention this evening a subject in which I have for a number of years felt a warm interest; indeed, to such an extent is this the case, that this lecture in great part will be a statement of my own experience. It will make no pretence to be any other than a record of my own conclusions on a subject of great practical importance.

THE GALVANO-CAUTERY IN NASAL SURGERY.

In 1873 I began a series of observations on the use of the galvano-cautery in the treatment of nasal disease. At that time the only battery available for the purpose was that of Burn's, an instrument which, notwithstanding the fact that its activity is dependent upon the immersion of the plates in a stationary bath, and the additional defect that currents of air are to be constantly transmitted through the fluid to secure efficacy, combines many advantages, among which may be mentioned its portability, the ease with which it can be cleansed, and, I may add, its durability, for the instrument at that time purchased has been in almost daily use for ten years. The greater number of these observations now recorded, therefore, were made with the Burn battery, although I have supplemented it in my practice with a larger, more efficient, yet bulkier instrument. At the beginning of my studies I was much discouraged to find that the conductors, the electrode, and the circuit maker, were all large, heavy, and imperfectly adapted for use upon chambers, so small and imperfectly illuminated, as are those of the nose. The cords were heavy and cable-like, and the electrodes adapted for the coarser purposes of surgery. In these respects they were admirably adapted (let it be understood) to all operations in general surgery, and especially to those involving vascular structures, such as the tongue. I desire to return my acknowledgments to Mr. Otto Flemming, of Philadelphia, to whom the problem was presented in 1874, to furnish for the purpose I designed, a more delicate electrode and a lighter and more available form of conducting cords. Without detaining you with the details of Mr. Flemming's efforts, aided by my own suggestions, I succeeded about the time above-mentioned in having prepared for my use a form of electrode which has remained to this day the basis upon which all similar instruments have been made which have been used by me (Fig. 1.) The electrode is simply a pair of delicate copper wires, measuring a little over one millimeter in diameter, separated throughout their entire lengths by asbestos, except at those portions which are continuous with a terminal platinum loop. The copper wires and asbestos are firmly wrapped with insulating silk, and the entire instrument when completed will present an average length of fifteen centimetres, a width of from two to three millimetres, and the platinum loop varying in length from three to fifteen millimetres. The weight of each one of these electrodes never exceeds 148 grains. Such an electrode is flexible, is readily cleansed, is light in weight, and is durable. The platinum loop at the end of the instrument can be modified in shape in ways already understood by electricians, and nothing novel is presented under that head. The extent, however, to which the platinum loop may be made to extend beyond the copper wires is a matter of much importance, if it is desired to make a linear eschar. It follows that the length of the platinum loop will determine the length of the eschar itself. When, however, a mere point of contact with the living membrane is desired, there is no objection to wrapping the electrode almost its entire length, thus leaving a mere tip of the platinum exposed. When it is desired to apply the cautery to the naso-pharynx, it is prudent to wrap every part of the instrument except its free end, in order that the posterior edge of the soft palate be not involved in the burn.

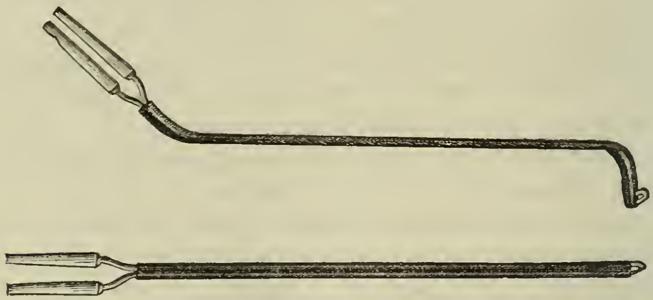

Fig. 1.—Two electrodes of peculiar shape in use by the Author.

The width of the cable with which I began my observations equalled about ten millimetres; but for the last year, I have succeeded in having very satisfactory results from a cord exactly one-half this width and of corresponding light weight. I desire next to call your attention to the battery which I have now in use, a battery designed by Dr. Carl Seiler and Mr. Otto Flemming, and known under their names. The novelty of the battery consists in the fact that the plates themselves are stationary, and the fluid is brought in contact with them by an upward motion which is determined by the pressure of the operator upon a treadle. The advantage of this method of bringing the plates in contact with the fluid is a decided one. The moment the foot of the operator is removed from the treadle, the current ceases, and there is no danger as is so often acknowledged to exist in the use of the Burn battery, of neglecting the plates and allowing them to remain in immersion a longer time than is needed.

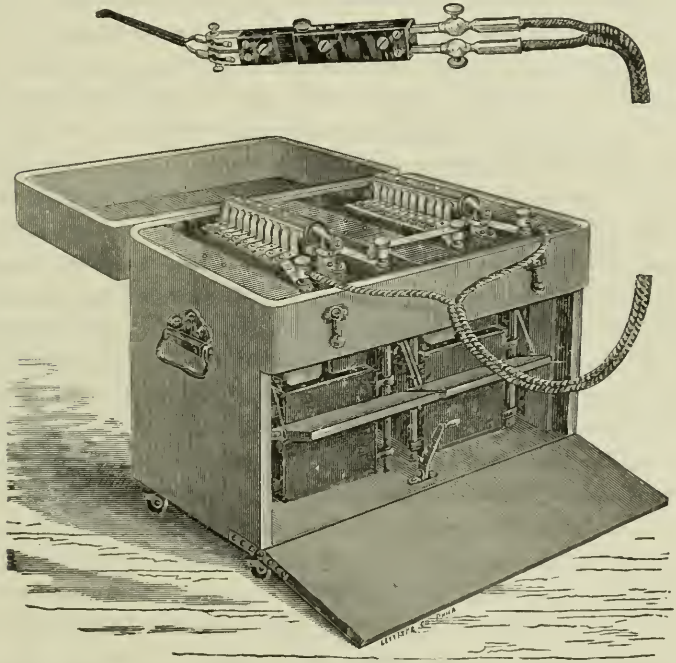

FIG. 2.—The double Seiler-Flemming battery employed by the Author. The two sets of plates are seen united by a flat band of metal. The case inclosing the two separate batteries opens in front, displaying the cells. The plates (which are seen pendant over the cells) and the treadle are shown. Above the figure of the battery lies a figure of the Flemming electrode-handle and the electrode in position.

We have in this apparatus an exceedingly powerful agent, especially when the battery is made of double strength, as I have of late been using it (Fig. 2); that is to say when two batteries (each one representing the chemical strength of that instrument known as the "Seiler-Flemming Battery," worked by a single treadle are united. A current from this powerful instrument is passed into a single short loop of platinum wire, and develops a heating effect of the highest destructive power. Yet the degree of heat is so rapidly evolved as to produce the desired effect upon the membrane with the least amount of pain. It may be held as an axiom in the application of the galvano-cautery, that the pain of an application is in direct ratio to a low degree of incandescence; or, expressed differently, the ease with which the applications can be borne is in direct ratio to the scintillating appearance of the loop and of the white color which attends incandescence. The single disadvantage associated with the employment of the white scintillating incandescence is the danger, or rather the liability, of fusing the platinum wire; but this can be readily averted by bringing the wire in contact with the tissues which it is destined to destroy, immersing the plates in the fluid, and then making a current. The contact should be of momentary duration, and be limited simply by the time which the will-power can press upon the button at the side of the current-maker. The moment the finger presses the button inward there is a quick flash of light from the electrode; the instant it is removed, the wire again becomes of the ordinary appearance of platinum; so that while the process of destruction is going on, the finger of the operator is opening and closing the circuit very much after the manner in which a telegraph operator works the Morse indicator. With one exception, which followed upon the incautious pressure of the button, thus making a circuit before the battery fluid was raised up against the plates, I have never fused a platinum loop. In the instance named the short interval of time which intervened between the appreciation of intense heat, which I had thus inadvertently maintained in the loop, and the time required for me to break the circuit was sufficient to fuse the wire.

It goes without saying that with a battery so powerful, great prudence is required in manipulating the electrode; but when properly used and with the precautions which naturally belong to the use of all surgical agencies whatsoever upon the living economy, I can say that the galvano-cautery in the treatment of nasal disease is absolutely safe. The single point which may be urged—that is to say, one which at least came to me with a sense of surprise—was the effect upon the tissues at the side of the platinum wire not in contact with it, but simply in its neighborhood. The tissues were thrown into a state of high vascular excitement by the presence of the heated loop near them; and one can very readily understand that the amount of radiant heat thrown off to the membranes in their immediate proximity from the heated wires would produce a roasting effect if long maintained in one position; but fortunately, almost all effects desired by the use of the cautery are obtained quickly; and two or three flashes of heat from the electrode, while it destroys the tissues which are in contact with the loop, do not have, in a chamber so moist as is that of the nose, any deleterious effect upon the adjacent surfaces. One of the most annoying effects in the use of the heated wire, is noticed in the removal of tumors from the roof of the naso-pharynx; for in this region the contact of the heated wire at the base of the growth is at the same time in close proximity to the structures at the orifice of the Eustachian tube, and the destruction of the tumor may go on coincidently with the roasting of the membranes at this orifice; but even in this instance the heated wire need be maintained for a short time only, as the loop is narrowed, it passes more and more toward the median line of the naso-pharynx and is to a corresponding degree, removed from the neighborhood of the tube.

The ease which the surgeon possesses of making eschars with this instrument, exposes him to the peculiar danger of attempting to do too much at a single sitting, and to hasten a treatment, otherwise tedious, by too often repeated or too deeply made applications. If the surgeon is desirous of reducing tumorefaction or swelling, I believe it is a rule, which should never be departed from, that the employment of extreme caution, producing slight effects with the wire at intervals of at least one day or two days apart, endeavoring to use the white heat in such a way as not to draw much blood, in other words to destroy the superficial or epithelial surface rather than the deep connective tissue or matrix, produces the best result in the long run. If, however, it is necessary to remove enlarged masses, the cautery-snare had best be employed in place of the electrode, (see p. 318). The slightest contact of the wire against the epithelium will at once carbonize the surface, while at the same time it will coagulate the albumen in the membrane beneath it. In this way, an effect is secured which is in every way comparable to that produced by caustics of the chemical group, such as nitric acid, etc.; whereas, if the destruction is deeply effected and hemorrhage ensue a lesion is established and the patient is subjected to the uncertainty attending a wound.

The wound may be the site of deposition of irritating substances in the air, of the diptheritic deposit, and at best is the location of tenacious clot-like exudations, which from the very fact that they form upon surfaces exposed constantly to the incoming and outgoing air soon become in part dessicated, and serve as sources of irritation to the surfaces already acknowledged to be in a morbid state. Whereas, if the surgeon is content to produce localized death by making firm coagula of albumen, these will be thrown off slowly (say from three to five days) and will leave beneath them a healthy surface, which, as a rule, does not a second time form an eschar. A small surface being covered at a single sitting, permits the operator to make applications to adjacent areas, without waiting for an eschar to come off from a given surface. I have often at a single sitting produced slight eschars in both right and left nasal chambers, the roof of the pharynx, and the tonsil. As a rule, however, it is desirable to make an application to one spot only at a single sitting.

In the order of the locations to which applications are to be made, may be mentioned first, the under surface of the middle turbinated bone, which can readily be reached by a small straight cautery, the head being thrown well back on the shoulders; second, the under surface of the inferior turbinated bone, which can be reached by a large straight electrode, the head being held in an easy position, and the floor of the nose being horizontal to the axis of the body; third, the roof of the naso-pharynx, which can be readily reached, either by thrusting an instrument directly through the nose into the pharynx, or by bending one at a convenient angle, and permitting a small amount of platinum wire to be exposed; fourth, the tissue at the outer side of the middle turbinated bone, corresponding to the region at which the maxillary sinus communicates with the nose; fifth, the region at the sides of the pharynx, and the orifice of the larynx. One of the most interesting of such methods of application is that of reaching the roof of the naso-pharynx through the nose. If a perfectly straight instrument, placed into the nose, and be thrust back along the floor until it reaches an obstruction, being allowed to remain in this position, and the rhinal mirror being employed to inspect the naso-pharynx, the end of the electrode will be found resting against the roof of the pharynx; so that the roof of the naso-pharynx can be burned with absolute freedom and impunity, within the limits above named, by simply taking the electrode and forcing it through the nose as far as it will go and burning the tissue against which it rests. In this way, diseased tissues at the roof of the pharynx can be successfully treated when it will be impracticable to inspect them by the use of the rhinal mirror, or indeed, in any other way than the one here indicated.

By the employment of cocoaine, the vessels can be notably constricted. In this way the soft cushiony masses of tissue can be held well out of the way (a very great advantage), at the same time, the cocoaine will exert its useful effect in obtunding sensibility. That the effect is to any extent that of a local anæsthetic, I have great reasons to doubt, but it is an exceedingly useful agent, and enables satisfactory treatments (often prolonged and tedious), to be borne by young children and nervous adults with the greatest possible satisfaction. It is curious that the cocoaine is ineffectual in some instances. I have now under my care a child six years of age, upon whom it has utterly failed. It produced no constriction of the vessels, and no diminution of sensibility. In other instances, I have remarked that the effect is exceedingly transient, lasting only for five, at the utmost ten minutes, and is practically of no use in controlling exaltations of sensibility. Dr. F. H. Bosworth, was the first to record the striking effects of cocoaine in constricting the blood vessels of the mucous membranes of the nose. It must, however, occur to any one who employs it, so decided are its effects in the majority of instances; but it is not a little curious that the first two patients upon whom I tried its effects were the two whose cases I have alluded to. The use of the cocoaine must not be forgotten in connection with the employment of high grades of heat in the electrode. I have never ventured to use it on a surface which was very vascular, without first freely using the cocoaine; for it is in every way probable that the scintillating white heat might cause free bleeding, no matter how little used, upon large uncontracted venous sinuses.

Since the weight of the handle of the electrode is considerable, it may under some circumstances be advisable to insert the electrodes (possibly one in either nasal chamber) and to touch lightly the free ends of the portions projecting beyond the nostrils with the handle of the electrode, at the time that the current is passed into the instrument by means of the interrupter. Of course, the moment the contact is made with the two poles of the electrode, there will be a flash of heat at the platinum loop which is lodged against the tissue desired to be cauterized. The advantage which is secured by applications made in this manner is conspicuous. In those patients who are unusually sensitive to pain or those who for any reason cannot properly control the motions of the head, such untoward disturbance cannot change the positions of the electrodes; for the backward and lateral motions of the head will simply break the contact between the electrode and the conducting wires. With the instrument in which the electrode and wires are firmly united (see Fig. 2), the motion of the head will often rudely disturb the position, cause cauterizations to be made in undesirable parts, and prove in every way to be annoying and unsurgical. In some instances, I have employed an electrode which retains a long, slender, flexible platinum loop, which can take any form desired by moderately exerted pressure, and which when thrust through the nose so as to touch the vault of the pharynx will conform to the curvature of that wall, and thus enable the operator to reach a point much further back than he possibly could by a straight, rigid instrument.

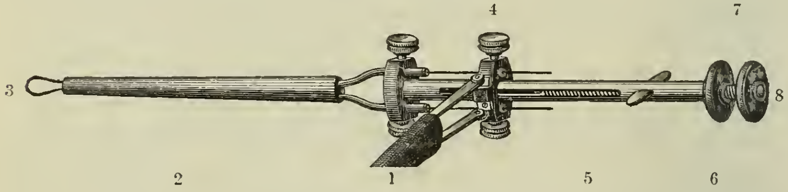

FIG. 3.—The galvano-cautery snare described in the text.—1. The cable of the battery; 2, the canula (which is not shown in full length); 3, the platinum wire; 4, the vulcanite carriage, with screws holding the ends of the platinum wire, with metallic contact with the hinge connections, by which the current is transmitted from the cables to the wire; 5, slotted barrel of aluminium; 6, a movable nut on the screw; 7, a small portion of the screw disengaged from the slotted barrel; 8, milled stationary screw-head.

A great advantage of the use of the galvano-cautery is its application to the principle of the snare. It is well known that a loop of wire which is steadily narrowed has great power in severing the attachment of tumors and other outgrowths. When of a large size they may be sufficiently powerful to pass through bony structures, as well as the softer parts of the body. The principle of the snare has been employed both in the throat, the ear, and the nose; but when my attention was first directed to this subject the forms available were too large and heavy for the delicacy of manipulation demanded in removing small tumors lodged in the narrower recesses of the nose. Moreover, no snare that I could then find would permit the galvanic current to pass through the loop at the time it was being narrowed. I was led, therefore, to inquire into the practicability of an instrument which would be at once light, of small size, and yet sufficiently powerful to remove that class of hypertrophied tissues and polypoid growths which are of such frequent occurrence in the nasal chambers. The instrument shown in Fig. 3 combines these qualifications, and satisfactorily performs the service for which it was designed. The only feature of an essential character which may be said to be novel is the fact that the platinum wire (3, Fig. 3) forming the snare is covered with a uniform coat of copper, except alone the portion forming the loop, which is bare. As a consequence of this arrangement the current of electricity from the battery is conducted through a double canula (1, Fig. 3) by means of the copper.

The slotted barrel (5, Fig. 3) of the instrument, including the milled screw-head (8, Fig. 3) is of aluminium. The carriage (4, Fig. 3) is of vulcanite. The cables (1, Fig. 3) are attached to the carriage by a swinging pivot, the invention of Mr. Starr, of the S. S. White Manufacturing Company. The weight of the instrument is less than half ounce. The canula measures four inches in length; the aluminium shaft four inches. The length of the instrument is therefore exactly eight inches when the screw and carriage are carried well within the shank but when withdrawn to its utmost the length of the entire instrument is nine and a half inches. The advantages of the electrical snare over others in use are; the facility with which the small loop can be carried against a small growth not exceeding the size of a grain of wheat or corn; the ability to grasp readily the pedicle, and by a few turns of the movable nut to cut its way into the tumor, when by an application of the current, all points of resistance can be easily overcome. The most vascular structures may be freely entered and divided. If a growth be hard, resilient, or of a size so large as not to enable the loop to be readily engaged upon its base, the wire is simply held against the side of the growth, when the current will gradually burn its way into the mass to any extent which may be determined by the operator. When it is in this way received within the growth, the loop may, as before, be narrowed and a portion of it removed. It will be seen that failure to remove at least a portion of the growth attacked is an event exceedingly unlikely to occur. I have been particularly struck with the facility with which hypertrophies of the inferior turbinated bone can in this way be treated, and if cocaine be freely applied before the operation, it constitutes, in my judgment, the most speedy and the least painful of any means by which such conditions can be reduced. The current passing through the battery to the instrument can be interrupted by any of the numerous devises with which the practical electrician is familiar, or the treadle of the battery can be depressed and locked, and the interruption of the current be determined by the pressure of the finger on the key in the handle. This is under all circumstances desirable, since the weight of the cells is sufficient to demand considerable force to be exerted by the foot, always enough to destroy the delicacy of the manipulation of the instrument.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 7.—Drawbaugh's Telephonic Inventions.

A history of the articulating telephone would be incomplete without a description of the instruments, which Daniel Drawbaugh of Eberle's Mills, Pennsylvania, claims that he invented, constructed, and operated considerably prior to the earliest date of invention claimed by Alexander Graham Bell. Drawbaugh claims to carry back the date of his invention to some time between 1860 and 1861. He claims to have constructed his first instruments a few years afterwards, and brings witnesses whose credibility and integrity appear unquestioned, to corroborate his testimony. From these witnesses it appears to be established that at an early date he was working on instruments designed to transmit speech through conducting wires, by means of electrical currents, and that he actually did construct such instruments, and successfully employ them in connection with some of said witnesses in the transmission of articulate speech. That he was so experimenting appears to be a notorious fact in the neighborhood in which he lived, as more than one hundred witnesses taken from among his neighbors amply testify, some of them pointing out and recognizing the original apparatus used. The direct testimony of so many apparently unprejudiced witnesses, which does not appear to have been successfully controverted, would seem to establish, beyond a reasonable doubt, the claims of Mr. Drawbaugh as one of the prominent followers of Reis in his invention of the speaking telephone.

Drawbaugh's inventions came prominently before the public during the famous suit between the American Bell Telephone Company and the People's Telephone Company, the latter Company being a corporation operating under Mr. Drawbaugh's inventions. This suit, which was noted for the length of time it has been pending, and the voluminous testimony introduced by both sides, was only recently decided against Drawbaugh in the United States Circuit Court, in the Southern District of New York.

It is not our intention, except incidentally, to discuss here the relative claims of Drawbaugh and Bell as to priority of invention of the forms of articulating telephones produced by them; nor to follow or discuss the decision of the court in the proceedings in equity in this case. Whether or not Drawbaugh can actually establish his claims in the court of last resort, we must leave to the final decision of such court. We desire rather to give merely such descriptions of the apparatus which Drawbaugh claims to have constructed, and in support of which claims he brings forward what appear to be reliable and trustworthy witnesses, as will acquaint our readers with the position he claims to occupy in the history of the invention of the telephone.

Whether or not Drawbaugh can explain his long delay in applying for letters patent by reason of straitened circumstances, or whether or not he can show due diligence in prosecuting his invention, and can thus establish the fact of non-abandonment of the invention we will not discuss; since neither of these questions can materially affect the operation of the apparatus we are about to describe.

The earliest date claimed by Mr. Drawbaugh for his first conception of transmitting speech by means of electricity was some time during his attendance at a course of lectures on Physics, delivered prior to 1860, near Milltown, by Prof. Heiges. The lecturer testifies that after the lectures Drawbaugh had frequent discussions with him on electrical subjects, and during these discussions expressed his belief as to the possibility of transmitting speech through wires by electrical currents. This would appear to fix the date of conception to some time prior to 1860. Drawbaugh, himself, however, testifies that his own recollection of the matter goes back to some time in 1861, during a visit to Washington, D. C., when he recalls a conversation with some parties respecting the electrical transmission of speech. The date of conception of the idea would, therefore, appear to be some time between 1860 and 1861.

The earliest form of transmitting instrument was made and used by Drawbaugh for the variation of an electric current by the human voice some time in 1866 or 1867. This instrument does not appear to have been preserved; Drawbaugh, however, testifying under oath, makes the sketch shown in Fig. 1, as fully describing the same

This apparatus, here shown, consisted of a cup *D*, of ordinary porcelain or earthenware, and therefore a non-conductor of electricity. Over the mouth of this cup, a diaphragm *B*, of flexible material was stretched and suitably secured to the rim. A metal rod *C*, was attached at its upper end to the middle of the diaphragm, and terminated at its lower end, in a metal plate *E*. A metallic wire *G*, passed down one side of the cup and was connected with a second metallic plate *D*, that rested on the bottom of the cup. Between the two plates *E*, and *D*, a material was placed, which was styled by Drawbaugh a "low conductor of electricity," that is to say, a high resistance. This material, which is shown in the figure at *F*, was, it appears, the subject of very numerous and frequent experimentation by Drawbaugh, and was made of different substances at various times. Among the materials tried, he mentions fine, clean earth, used either alone or in combination with plumbago, or plumbago alone was employed, or finely pulverized charcoal. The cup apparatus was placed in the circuit of a voltaic battery and with some form of receiving instrument.

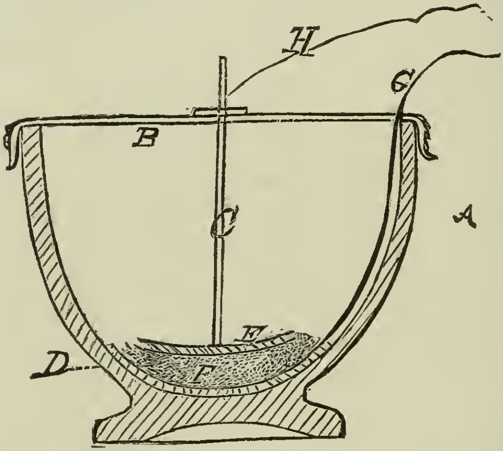

FIG. 1.—Sketch of Drawbaugh's Early Form of Transmitter.

The interest attached to this early form of instrument, asssuming of course, that it was constructed as claimed, and placed in the circuit of a voltaic battery and receiving instrument, at a date as early as some time in 1866 or 1867, arises of course from the fact that it contained in it the essence of the invention claimed by Bell as being essential to the very existence of the articulating telephone; viz., the means whereby an electrical current could be set by the human voice, into undulations, as distinguished from the intermittent currents, which it has been claimed are necessarily transmitted by the old form of Reis transmitters. For, the instrument designed by Drawbaugh was intended to be used as follows; viz., the speaker, talking against the membrane *B*, caused it to be set into vibrations by means of the sound-waves impinging thereon. The movements of the diaphragm, so produced, causing the plate *E*, to move towards and from the plate *D*, subjected the material *F*, to variations of pressure, and consequent variations of resistance, and thus threw on the circuit of the battery the so-called electrical undulations which have been assumed as necessary to the successful transmission of articulate speech.

The issue here raised between Bell and Drawbaugh, is, it will be seen a vital one. Since all that has been claimed for Bell, as of essential novelty in telephony is, we believe, practically, limited to the production of an undulatory current as distinguished from the so-called pulsatory or intermittent current of the Reis transmitter. If then, Drawbaugh can clearly establish the fact that at this early date, he constructed and operated such a form of transmitting instrument, he entirely removes Bell's claims as the inventor of such a device, in the broad manner which Bell endeavors to hold.

The early form of receiving instrument used in connection with the original cup-transmitter appears to have been of the form of a magnetic diaphragm receiver, somewhat similar to the form in which a non-magnetic diaphragm, such as bladder or other membraneous material, has connected with it a magnetizable material serving as the armature of an electro-magnet placed in the circuit of the transmitting instrument. Its form, and the arrangement of its details, as claimed by Drawbaugh, is shown in the sketch in Fig. 2.

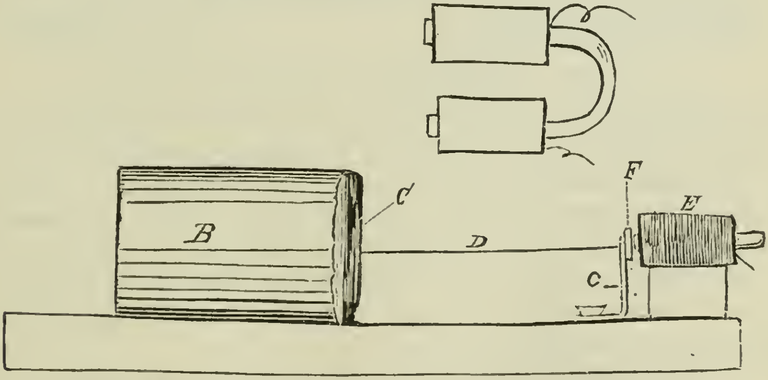

FIG. 2.—Sketch of Drawbaugh's Early Form of Receiving Instrument.

A tin can *B*, without top or bottom, was covered with an elastic diaphragm *C*, of membraneous material and mounted, in the position shown, on a suitable support. An electro-magnet *E*, had its armature

F, supported on a spring arm *G*, secured to the base in the position shown. A cord, or string *D*, attached to the centre of the diaphragm connected it with the armature *F*, of the electro-magnet. The tin can *B*, was coated on the inside with plaster of Paris, under the impression that the sound produced in the can by the movements of its diaphragm would thereby be improved.

This receiving apparatus was connected with the cup-transmitter and a voltaic battery, in the manner indicated in the sketch of Mr. Drawbaugh shown in Fig. 3.

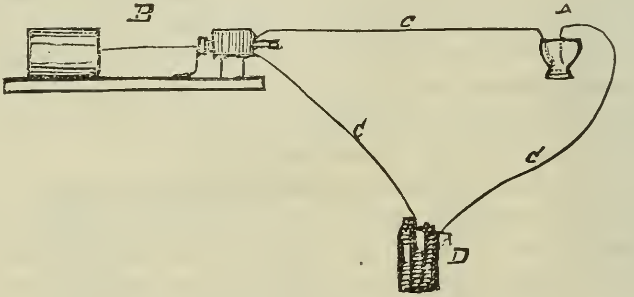

Fig. 3.—Sketch of Drawbaugh's Telephonic Circuit.

In this figure the receiving instrument is shown at *B*, and the cup-transmitter at *A*. These instruments were placed in the circuit of the voltaic cell *D*, by the circuit wires *C*, *C*, *C*, as shown.

Concerning the success of this early form of instrument, Drawbaugh testifies in his direct examination.

"72 Q. In the use of that old cup machine for the transmission of sound by electricity, did you succeed in transmitting any sounds through it, so that they could be heard?

"A. Yes sir, I did; but I don't want it to be supposed all parts of sentences, some words but feebly; I tried sounds, different sounds made in the way of noises. I don't remember what different sounds, but I could distinguish different kinds of sounds more distinctly than I would words. What I wish to convey by that is, that I could distinguish the difference between different sounds.

"73 Q. Could you or not by that old cup machine, distinguish vocal sounds from other kinds of sounds?

"A. Yes sir, I know that the results I had there, were sufficient to encourage me to go on with the experiments."

Drawbaugh claims that subsequent improvements in transmitting instruments enabled him at an early date in his investigations to obtain from the same form of receiving instruments what he termed "true copies" of the sounds transmitted, and permitted him to hold conversation and transmit whole sentences intelligibly.

A slight modification of this form of receiving instrument, made as claimed by Drawbaugh some time afterwards, in 1867–1869, is shown in Fig. 4, in plan and elevation.

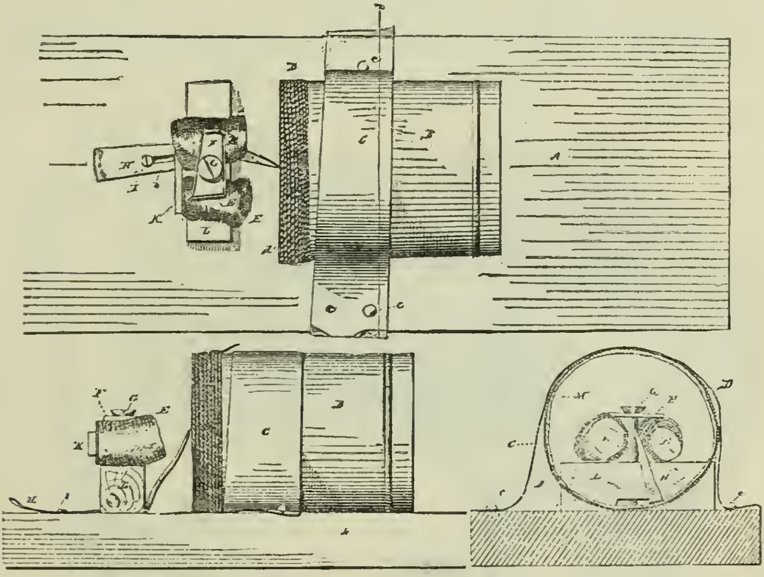

FIG. 4.—Drawbaugh's Early Form of Receiver. (Exhibit B.)

In this figure, the cylinder *B*, which was formed of what is apparently an old tin mustard box, was fixed to the base board *A*, by the tin strap *C*, fastened to the board by tacks. An electro-magnet *E*, *E*, formed as shown, mounted in front of the end of the tin box that was covered by a membraneous diaphragm. *H*, is a tension plate, adjustable by means of the slot *h*, and set screw *i*, its end terminated in a little strip that is supported in an upright position in front of the diaphragm. Its purpose was to provide a ready means for varying the tension of the diaphragm, as also to prevent the armature attached to the diaphragm from striking against and adhering to the poles of the electro-magnet.

Subsequent modifications were given to this receiver during repeated experiments made on it by Drawbaugh. It will be seen that in its essential details it is the same as in the earlier form, as shown in Fig. 5.

In this drawing the hollow cylindrical receiver is shown at *B*, secured to the base board *A*, by means of the strap *C*. A diaphragm D^1, of animal membrane, is securely fixed to one end of *B*, by means of cord *H*, wrapped around the end in the manner shown. The electro-magnet *E*, is supported on a block so as to have its poles near, but not in contact with an armature *d*, fixed to the centre of the diaphragm. The plate *G*, with its regulating slot *g*, and set screw g^1, is provided for regulating the tension of the diaphragm and preventing the armature *d*, from coming into contact with and adhering to the magnet poles.

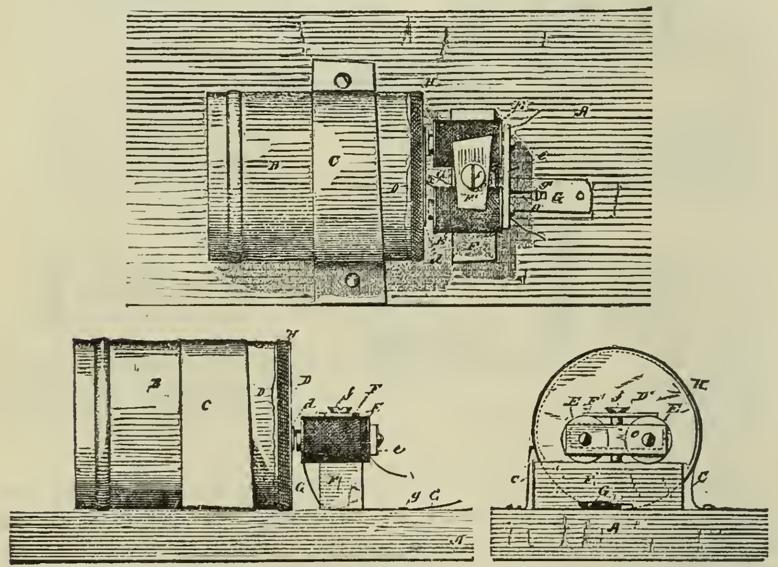

FIG. 5.—Reproduced Form of Drawbaugh's Early Receiver. (Reproducing Exhibit B.)

The next form of transmitting instrument is shown in Fig. 6.

The tumbler transmitter, as will be seen by an inspection of Fig. 6, was similar in the arrangement of its parts to the old cup transmitter. The pulverized low conductor, however, instead of being placed in the bottom of the tumbler was placed between two metallic plates suitably supported near the middle of the tumbler.

The disposition of parts were as follows: *A*, is a glass tumbler, lined with a thin layer of plaster of Paris, A^1. A wooden cup, *B*, serving the purpose of a mouth-piece, is securely attached to the top of the tumbler. This also is lined with plaster of Paris, B^1. A membranous diaphragm was attached to the top of the tumbler. The low conductor was placed between the two metal plates, *D*, and *E*; the adjustable rod, *C*, provided for the support of the lower plate, *D*, passed down the side of the tumbler. The wire, *c*, was intended for connection with the upper plate, an old soldered joint showing at *d*. The rod *D*, served for the electrical connection to the lower plate.

This transmitter, when in use, was of course placed in the circuit of a battery with the receiving instrument we have already described.

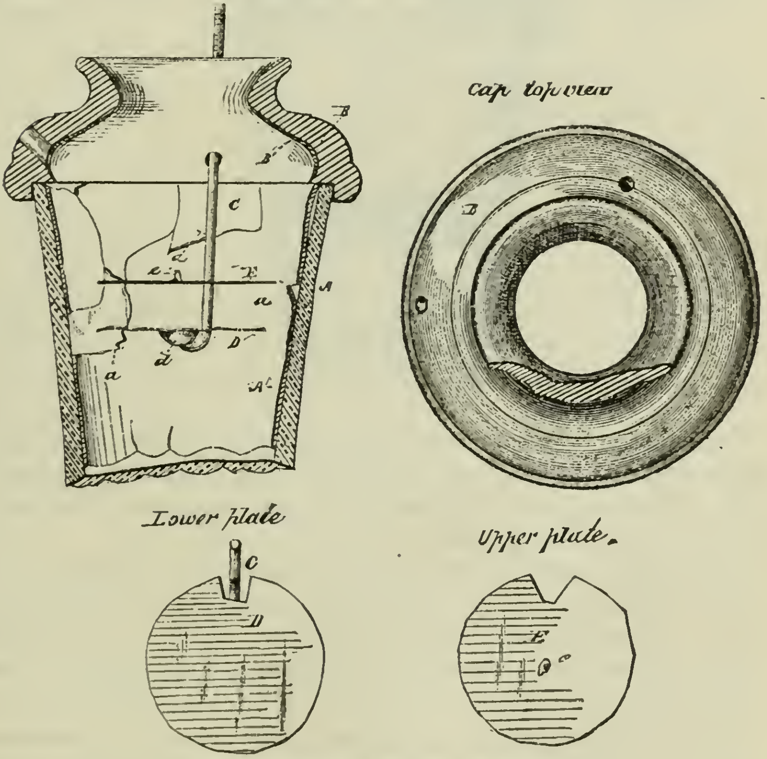

Fig. 6.—Drawbaugh's Tumbler Transmitter.

The tumbler as originally used was entire, and Drawbaugh testifies that, in order to improve the action of the powdered low conducting substances that he placed between the plates *D*, and *E*, he was in the habit of moistening them by placing a little water in the bottom of the tumbler. During the frequent experiments with this instrument the bottom of the tumbler broke off, as is represented in the drawing. He still continued to employ the instrument, and thus found that the moisture of the conductor did not have the beneficial effect he had formerly ascribed to it.

The results of experimentation with this instrument finally produced the modification shown in Fig. 7, which, it is claimed, is a reproduction of the apparatus as Drawbaugh made it at this early date.

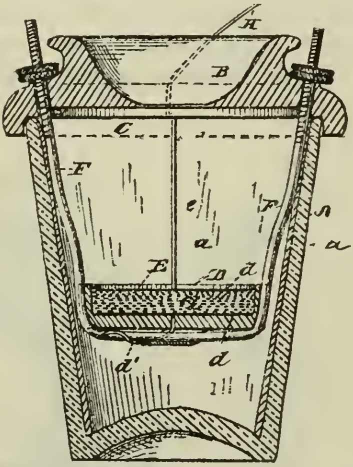

FIG. 7.—Drawbaugh's Tumbler Transmitter. (Reproduced.)

One difference observable in this later form of instrument is in the shape of the conducting rod provided for the support of the lower plate. Here it is bent in the shape of a yoke, and passes down inside of the tumbler, under the plate, and up the opposite side.

A, is a glass tumbler, with its lining, *a*, of plaster of Paris. The wooden mouth-piece, *B*, is provided with a diaphragm of tin, and is securely attached to the top of the tumbler. *D*, is a cup of wood, designed to hold the powdered low conductor, and supports the lower metallic plate, *d*. The box is itself supported by the yoke-shaped conductor, *F, F*, placed as already described. The ends of the conductor, *F, F*, are provided with set screws for the purpose of permitting the ready adjustment of the position of the box, and hence of the pressure on the conductor. The upper metallic plate rests on the surface of the conductor, and is rigidly connected with the diaphragm by the rod *e*, formed of conducting material. A marked alteration in the shape of the mouth-piece must also be noticed.

This later form of apparatus shows a great advance on the one seen in Fig. 6. In the substitution of a metallic diaphragm for the membranous diaphragm of the former instrument a great step was taken by Draybaugh in the improvement of the articulating telephone. Apart from the fact that membranous diaphragms are greatly affected as to their tension by the hygrometric state of the atmosphere, the mere moisture in the breath of the speaker was apt to introduce differences in the tension of the diaphragm that were very apt to throw the low conducting powder out of the pressure best adapted for the most successful operation. Drawbaugh testifies that in the early stage of his experimentation he frequently employed diaphragms of thin metallic substances, generally employing tinned iron for the purpose.

Assuming the correctness of the statements of Drawbaugh concerning his experiments as to the effects of pressure on powders of low conducting substances, it would appear that at this early date he had already reached the point attained later by Edison, who afterwards independently worked in the same direction.

Drawbaugh's ideas concerning the nature of the action which pressure exerts on the electrical conducting power of powdered substances, appears from his direct testimony to be somewhat as follows, viz.: when in the state of a loose powder, the particles of the substance are separated by non-conducting air spaces, and conduct or pass the electricity through the mass of the solid substance at the points of contact only. The effect of pressure being to increase the number of the points in contact, or their breadth, or both, would necessarily have increased the amount of current that would pass through the conductor.

It appears, therefore, that the idea conceived by Drawbaugh at this early date was quite plausible, and shows that he reasoned with considerable power concerning the nature of his experimentation.

The comparatively small space between the mouth-piece and the diaphragm also marks a great improvement. Drawbaugh appears, in the various instruments he constructed, to have devoted considerable time to experimenting with mouth-pieces of vaious shapes. The shape of the mouth-piece shown in Fig. 7, is the one that is now generally employed in the art, as giving the best results in the transmission of articulate speech, and, indeed, in the receiving instrument itself, in the reproduction of the transmitted speech. Most of his first diaphragms were large and high, and necessarily contained a large amount of air. As early in his experiment, however, as the date of the later tumbler transmitter, it would appear that he ascertained, as the result of repeated trials, the good effects of small, low mouth-piece.

The use of the wooden cup for the reception of the pulverized low conductor was not in itself much of an improvement. Its adoption by Drawbaugh was for the purpose of experimenting as to the effects of moisture on the action of the low conductor. He had tried the effects of actually wetting them by pouring water over them, and finding that this greatly interfered with their action, he devised the cup for the purpose of leaving a space below the low conductor in which he placed water, thus permitting it to slightly moisten the pulverized conductor by evaporation. We have already pointed out how the accidental breaking of the bottom of the tumbler enabled him to ascertain that the presence of moisture was not beneficial as previously believed.

The elimination of the error of moistening the pulverized low conductor appears to have enabled Drawbaugh to achieve greater success in his experiments with different forms of resistances. In replying to a question as to the nature of the substance used in the tumbler transmitter he testified, "I don't remember whether I used earth in the tumbler transmitters; in the former instrument, that is, in the cup, I used earth; in this or the tumbler instrument, I had used plumbago alone, and I had used plumbago mixed with other materials; that is with carbons, and pulverized charcoal and plumbago; and at times I had used charcoal alone; at other times finely divided coke and charcoal mixed, and also pulverized coke alone. I had used bronze, that is, finely divided metals, mixed with carbon or coke. I generally had bronze in the shop."

As to the successful use of the tumbler transmitter with the tin can receiver already described, the testimony of apparently credible witnesses show that they were repeatedly used for the transmission of intelligible, articulate speech. They were used on a telephonic circuit placed in Drawbaugh's shop, and run in various directions. These experiments extended over several years. The shop had a basement nearly underground. The next story above connected with the basement by a staircase. Another staircase communicated with room above. Doors placed in the upper rooms shut them off from each other and from the basement.

As to the manner of trial we will quote in the language of an answer by Drawbaugh in his sworn testimony.

"I sometimes would have the transmitter in the cellar; that would be three floors or stories below where the receiver would be; I mean the third story below. I also tried them in different rooms, having the transmitter in one room and the receiver in another, on the same floor; I also tried them with one floor between them, one in the part of the shop where we worked, and which we called the first story, and the other in the story next above that; oftentimes I would have one instrument on the second story at one end of the shop, while the other instrument would be on the first story at the opposite end of the shop. I am positive that the sounds received or produced came through the instruments."

The circuit wires were arranged in different ways, passing through the walls and ceilings, and fastened to the same. At times he increased the electrical distance between the transmitting stations by the introduction of a large coil or roll of wire into the circuit. He also experimented with ground and return circuits, and with metallic circuits.

The circuits thus established, it is claimed, were tested in various ways. He would place a clock or watch in the neighborhood of the transmitter and listen at the tin can receiver. Whenever he could press people into the service he would place them either at the transmitting end or at the receiving end. He would read some advertisement or other matter at the transmitter and then go to the party at the receiver and get him to repeat to him what was heard, or he himself would listen and repeat the message orally afterward to the party sending it.

Drawbaugh's first form of telephone did not therefore belong to the class of magneto-electro instruments in which the sound waves produce the currents necessary for the transmission of speech. It was an instrument that belonged to the class of transmitters in which the action of sound waves on the diaphragm of the transmitter varies the electrical resistance of a current that already exists.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, March 12, 1885.

(To be continued.)

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE METZLER & BURRELL SIGNAL-LANTERN.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, *June*, 1884.

The Sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination

THE METZLER & BURRELL RAILWAY SIGNAL-LANTERN,

reports that, the invention is a signal-lantern for railways having two globes, one forming the upper half of the lantern body and the other the lower half. A single lamp, which is fixed immovably to the bail of the lantern, supplies light to either of the globes as may be desired, the body of the lantern being made to rotate upon a central axis around the lamp, so that one or the other of the globes may thus be illuminated in turn.

The globes are of different colors. They may be of any two colors which it may be found desirable to combine for use in signaling; but, in reality, red and white, and red and green are generally combined, these being the two combinations which are found most serviceable for use in signaling by trainmen and crossing-flagmen.

The object of the invention is to provide trainmen and crossing-flagmen with a lantern which they can use for giving their usual safety signal, and which they can instantly convert into a danger signal in case of necessity, by simply reversing the body of the lamp, thus turning the globes end-for-end.

The advantages of thus combining two signals in one lantern are two-fold:

First.—It enables the railway companies to dispense with one-half the number of lanterns they usually require, thus entailing a decided economy in the item of cost for lanterns, wick, cleansing, etc., and

Second.—It places a danger signal, at all times, at the instant service of the trainmen and crossing-flagmen, a circumstance which may frequently enable them to avert a serious accident.

The Committee is of opinion that the invention of Messrs. Metzler & Burrell is one of great utility and is worthy of the highest commendation which the Committee on Science and the Arts can bestow.

(Signed) LUTHER L. CHENEY,
RUFUS HILL,
WM. P. COX.

Adopted *Dec.* 3, 1884.
(Signed) H. R. HEYL,
Chairman.

[SEAL.]
I certify that the above is a true
copy from the record.
(Signed) WILLIAM H. WAHL,
Secretary.

Book Notices.

THE MATERIALS OF ENGINEERING. PART III. NON-FERROUS METALS AND ALLOYS. By Robert H. Thurston, A.M., C.E. etc. New York: John Wiley & Sons, 1884. 8vo, pp. 575.

Part III of Professor R. H. Thurston's MATERIALS OF ENGINEERING is devoted to the consideration of such of the non-ferrous metals as are really available for the purposes of the engineer. These are chiefly copper, tin and zinc and their numerous alloys; but Prof. Thurston also describes at greater or less length all the metals used in construction, and completes the list by a brief enumeration of the rare, or precious metals, whose qualities do not in general fit them for use in construction and whose first cost renders their employment impracticable even when they have properties of a valuable kind.

Chapter I touches on the history of the use of metals as far as we are able to trace it, and also treats at some length on their physical peculiarities and the methods employed in reducing them from their ores. The "useful" metals are described as iron in its various forms, copper, lead, tin, zinc, antimony, bismuth, nickel, and occasionally aluminium and others of the rare metals. The special qualities of the so-called "useful" metals are defined as *strength*, *hardness*, *density*, *ductility*, *malleability*, *fusibility*, *lustre*, and *conductivity*, and in a series of tables the metals are compared as to the degrees in which they possess these various properties.

Chapter II describes the non-ferrous metals more at length, describes the various ores, the chief localities in which they are found, the treatment of the ores, the various uses of the different metals in the arts and their comparative cost. The properties of alloys in general, their chemical nature and physical qualities are treated in Chapter III, while the two succeeding chapters consider in turn the copper-tin alloys or bronzes and the copper-zinc alloys or brasses. The Kalchoids, alloys of copper, zinc and tin, and miscellaneous alloys of various metals, alluminium bronze, German silver, Babbitt metal, etc, are described in Chapter VI, while the manufacture and working of the various alloys used in the arts is discussed in Chapter VII.

The remainder of the book, with the exception of the last chapter, is devoted to the consideration of the strength of the non-ferrous metals and their alloys and the conditions which modify or affect their strength. A great deal of information has been collected from various sources, the results obtained by many observers are given, extracts made from investigations of the author and others for the United States Government Board.

Attention is again directed to the peculiar behavior of the various metals under continued stress or intermitted strain. It is noted that one class of metals, called by the author the "Iron Class," exhibits an elevation of the elastic limit, when subjected to a continued strain, while in the other, or "Tin Class," a corresponding depression occurs under the same circumstances. Thus the one actually becomes stronger under a continued strain, if that strain does not exceed the breaking strength, while the other will fail at last under a load which it bore at first without yielding. From this fact it is obvious that the greatest care must be exercised to select a sufficiently large factor of safety, when we employ the metals of the "Tin Class," in constructions subjected to constant strain; and further that the breaking strength as determined in the ordinary way by rapid rupture cannot be relied upon as a measure of the strength after subjection to strain.

The fourteenth and concluding chapter bears the caption "Mechanical Treatment of the Metals," and describes some of the methods employed to increase the strength or remove the defects of the metals as found in the market. These methods of manipulation are chiefly such as change the volume, density and molecular condition, by causing flow while under stress. Among such processes may be mentioned cold-rolling, wire-drawing, forging under the drop, the hammer, or the hydraulic press, cold-hammering, annealing, etc. That which has probably attracted of late the greatest attention is Whitworth's process of producing solid steel castings, by subjecting the molten metal to a very heavy pressure under the hydraulic press, while the processes of contraction and solidification are being completed. A pressure of twenty tons to the square inch is said to produce all the compactness, density, strength and ductility of a steel forging, and the shrinkage under pressure amounts to an inch and a half for every foot of length. A similar process has been employed with excellent results by Colonel Lavroff in the manufacture of cast bronze guns. Methods have also been employed to increase the efficiency and durability of bronze ordinance by processes of cold working, such as enlarging the bore by forcing a succession of plungers of increasing size through it, and hardening the surface by a process similar to rolling.

In conclusion we would note that while a very large proportion of the matter of this volume has already appeared at various times in other publications, the compilations here presented will no doubt prove a valuable aid to the engineer, and an instructive text-book for the student. S.

SULPHUROUS ACID IN THE ATMOSPHERE.—The general composition of the atmosphere is nearly constant, whatever may be the place or the height at which the air is taken. Sulphurous acid, however, is sometimes found in considerable quantities in the atmosphere of large industrial towns. From a long series of experiments at Lille, M. A. Ladureau, the director of the State Laboratory, found that the air contained 0·18 cubic centimetres of sulphuric acid per hectolitre, or 1·8 cubic centimetres per cubic metre. With a view of ascertaining whether this proportion was constant or variable according to the state of the atmosphere, he instituted special experiments and found that in calm weather the proportion rose to 2·2, while in strong winds it fell to 1·4 cubic centimetres. This fact is easily explained if we reflect that sulphurous acid gas, on account of its considerable density, tends to fall to the lowest portions of the regions where it is produced; it accumulates there upon days when the atmosphere is calm in greater proportion than when the wind has mingled the upper and lower layers of the atmosphere.—*La Nature*, March 29, 1884. C.

SPECIAL STAGE EFFECTS.—For an artificial moon M. Brandt uses a square frame containing eight Edison lamps. The anterior face of the frame is mounted with a translucent disk. The intensity of this artificial moon can be increased to 2,000 candles, which would be impossible in so small a space with gas, on account of the excessive heat. In order to produce apparitions, on a scene which is completely dark, small incandescent lamps are screened by an opaque covering, under the gauze which surrounds the character which is to appear. At the proper moment the light is opened upon the gauze so as to make an apparition of magical beauty. In like manner the sword, in Wagner's opera, *Walküre*, is illuminated suddenly by a small incandescent lamp, the light of which seems like a ray flashing from the sword. Contrivances have also been made for making stars shine on the heads of ballet dancers, whenever desired.—*Lumiere E'ectr.*, May 24, 1884. C.

COMPARISON OF COLORED RINGS.—When a copper plate is exposed to the flame of an alcohol lamp, a Bunsen burner, or an enameler's lamp, irridescent rings are produced around the heated point. Under favorable circumstances the colors become fixed, and apparently unalterable by the air. These thermal rings are like the electro-chemical rings of Nobili; like them, they follow one another and are propagated in waves. In both cases the colors are arranged in the same order as in Newton's rings when seen by transmission. Multiple thermal rings may be formed by means of metallic ajutages attached to drums, which are surmounted by two or more gas burners. The same apparatus may be used for the production of electro-chemical rings by placing steel needles of uniform length in the fine openings of the tubes. Decharme has sent a memoir to the French Academy, containing a comparative table and plates of the two kinds of rings, showing that the resemblance is maintained even in details. The resemblance becomes most striking when the jets of flame are small and slightly oxidizing.—*Comptes Rendus*, Sept. 1, 1884. C.

MAGNETIC PLATES.—When a thin plate of steel is placed in a uniform magnetic field, so that the lines of force are normal to the surface of the plate, there is formed a very flat magnet, of which the two faces are the two polar surfaces. The magnetic distribution, thus obtained, seems to disappear as soon as the plate is removed from the field. M. Duter employed tempered steel plates, with the thickness of a millimetre and diameters varying from 5 to 40 mm., with which he formed cylindrical piles. In some of these piles the plates were directly in contact, while in others they were separated by the use of paper or pasteboard. The piles were placed in the central portion of a very powerful magnetic field, and after they were withdrawn, they constituted regular permanent magnets, the sustaining force being greater in proportion as the plates were closer to one another. On dismounting the piles and carefully marking the upper and under surfaces of each plate, the magnetism was hardly perceptible; but when the pile was reformed, there was again a regular magnet, although weaker than at first. The separation of the magnet into its constituent elements and its reconstruction can be continued indefinitely.—*Comptes Rendus*, July 21, 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, March* 18, 1885.]

HALL OF THE INSTITUTE, March 18, 1885.

WILLIAM P. TATHAM, President, in the chair.

Present—260 members and 105 visitors.

The minutes of the last meeting were read and approved.

The election of eleven new members was reported since the last meeting of the Board.

The paper for the evening was read by Mr. Frederick E. Ives, of Philadelphia, subject: "Isochromatic Photography," in which the author presented his claims to priority in the discovery and announcement of a practical procedure of producing photographic plates which are equally sensitive to every part of the visible spectrum, and by which he succeeded, as early as 1879, in producing pictures which brought out the full values of all those colors which photograph too dark by the ordinary methods.

Mr. Ives' paper has been referred to the Committee on Publication.

Prof. Edwin J. Houston, by request, gave a historical summary of the subject of autographic or fac-simile telegraphy, with especial reference to the recent advances in this direction accomplished by Mr. Patrick B. Delany, of New York. The speaker exhibited a number of specimens illustrating Mr. Delany's method of fac-simile transmission.

Prof. Houston's remarks have been referred for publication.

The Secretary's report embraced remarks on the efforts now being made by the U. S. Signal Officer to utilize the balloon as an aid in meteorological research; on the future of the glass industry in the United States; and on the progress made in the preparations for the forthcoming "Novelties" Exhibition to be held under the direction of the Institute in the autumn of the present year.

The following scientific and mechanical novelties were shown and described: on behalf of Jas. W. Queen & Co., of Philadelphia, laryngoscopes, otoscopes and ophthalmoscopes for surgical uses, supplied with minute Edison incandescent lamps; on behalf of J. C. Finn & Co., of Philadelphia, specimens of new materials for wall coverings, etc.; Wm. Walters' design for city subways; J. M. Williamson's improvement in vehicle wheels, and W. B. Eltonhead's improved nut-lock.

The Secretary exhibited a series of photographic views illustrating a number of the more noteworthy objects of interest in the World's Fair at New Orleans. These views were loaned for the purpose by Mr. Edward L. Wilson, of Philadelphia.

Mr. Thos. Shaw spoke, in very complimentary terms, of the services of Mr. D. S. HOLMAN, until lately Actuary of the Institute; and, in conclusion, moved that the thanks of the Institute be tendered to Mr. Holman. The motion was numerously seconded, and, on being put to vote, was unanimously adopted.

Adjourned. WM. H. WAHL, *Secretary.*

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(To be Continued.)

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ACTINISM.*

BY PROFESSOR CHARLES F. HIMES, PH.D.

Col. CHAS. H. BANES, Chairman of the Committee on Exhibitions introduced the lecturer with the following remarks:

LADIES AND GENTLEMEN:—It has been the earnest desire of those in charge of the preparations for this exhibition, to give it an educational character; and they have sought by all means at their disposal to develop this feature to the fullest extent. One of the most useful and popular means which they have adopted to attain this object, is the present course of lectures upon topics appropriate to the place and the subject of the exhibition, and the Committee in charge of this work have been most fortunate in securing the co-operation of a number of eminent men of science.

I have great pleasure in introducing to you Prof. Charles F. Himes, of Dickinson College, who will lecture this evening on the subject of "Actinism."

Prof. HIMES spoke as follows:

LADIES AND GENTLEMEN:—The branch of science which considers the chemical changes produced by the action of light—named many years ago by Herschel, Actino-chemistry—has been so developed within recent years, that it has won its way to recognition as a most important, as well as interesting field of investigation. But, apart from its intrinsic interest, there seems to be an especial appropriateness in its consideration at this time, and in this place. Electrical illumination has converted night into day upon your streets, has rendered your shopkeepers independent of sunlight; and it promises, also, by reason of its richness in those very rays that effect chemical changes, to render those who employ the actinic power of light equally independent of the variable and uncertain light of the sun.

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* A lecture delivered at the International Electrical Exhibition, October 2, 1884.

Our treatment of the subject this evening must necessarily be controlled by the limited time at our disposal, and it has seemed to me that the most may be accomplished by adopting as a general plan, as indicated in the syllabus, first, a rapid survey of the leading facts, as they present themselves in the development of the science, and the illustration of these by typical experiments, and then a consideration of these, as far as possible, in their connection, as explained by the wave theory of light. Uniform treatment of the subject is almost as necessarily excluded as exhaustive treatment, and it will be found necessary to pass by features of the highest interest, and possibly of even greater importance than those presented, without even an allusion. Again, whilst photographic processes and manipulations, as such, do not constitute the subject for our consideration, we will find it convenient, and even necessary, at times to employ the terms and processes of photography; but we will do so only in so far as they may assist in the discussion of those general facts and principles that constitute the scientific basis of all photographic practice.

The fact that a pure white compound of silver, called by the alchemists horn silver, by us silver chloride, darkens in the light, was the first observed chemical effect of light, and occupies, in this connection, the same place that the attractive power imparted to amber by friction occupies in the history of electrical science.

I have here, in a protected roll, a piece of paper, coated with a thin layer of this substance. I unroll it, as you see, in the mellow light of these incandescent lamps, without any precaution whatever. That light, comfortable as it is to the eye, is comparatively feeble in its effect upon silver chloride. But Mr. Knapp will expose it for a short time to the light of our arc lamp, and, that any effect produced may be more readily noticed, I will first cover it with this cardboard, with a design cut out of it, so that a portion of the paper will be completely protected, whilst the other portion will receive the full effect of the light, and we may thus have the advantage of the contrast. In giving this fact the prominence I do, as the first observed in this connection, I do not, of course, ignore the general observation of the effect of light upon animal and vegetable life. That forced itself upon the attention of man in all ages. The necessity of light for healthy animal and vegetable growth, for the production of color in the flower and bloom upon the fruit, of course could not be overlooked. But in all these cases the action of light is so complicated with so-called vital processes, controlled by so-called vital force, that there is scarcely a hint at its action *per se.* The darkening of this compound, noticed as well by miners in an ore of silver as by the alchemists in a laboratory preparation, was unique, in that it was entirely uncomplicated with mysterious vital processes, in that it was purely a laboratory experiment, that invited investigation by ordinary methods.

You notice now, as I uncover this paper, returned to me by Mr. Knapp, after exposure, as you have seen, to the light of the arc lamp, how the unprotected portion, represented by the design cut out of the cardboard, has been decidedly darkened. This has been accomplished in less than a minute. Any one conversant with photographic practice will understand what that means, and will be surprised at the wonderfully actinic power of this arc lamp. For this substance darkens but slowly in diffused sunlight. Now, just as the isolated observed fact in electricity awaited Gilbert to expand it into a branch of science, so this fact waited until, about a century ago, Scheele, the eminent Swedish chemist, undertook its systematic investigation, and did for actino-chemistry what Gilbert had done for electricity. He explained the change effected by light, *practically*, as we understand it to-day, as a separation of chlorine. But he did more. The query arose in his mind, whether all the rays of sunlight were equally effective. He investigated the problem experimentally. Availing himself of the beautiful discovery of Newton, he threw, by means of a prism, the particolored band of light called the spectrum upon the floor of the room, and in it placed powdered silver chloride. He found the effect greatest at the blue end. We have not sunlight at our disposal to repeat this experiment as he did; but we will avail ourselves of our arc light, which we have already tested as to its actinic power. The beautiful spectrum you now see upon the screen is similar to his. In it we will now test the actinism of the extreme ends—the blue and the red portions. We will employ an ordinary photographic glass plate, sensitive to light, so that the result can be exhibited by the lantern upon the screen. But first, in this case, all our incandescent lamps must be turned off. The reason for this will be apparent as we proceed. Now, with the assistance of Mr. Knapp, as you see, one end of our plate is exposed behind one half of a stereoscopic negative in the red end of the spectrum, and now the other half is held in the same way in the blue end of the spectrum. The exposure in each case has not exceeded thirty seconds. I now pass the plate to the photographic assistant, to be developed, with the request that the developed plate be exhibited to us, in time, by means of the lantern upon the screen. Whilst we await the result I will consider some very natural queries that may have arisen. Why is this experiment conducted so differently from that of a moment ago? Why are the results not exhibited at once, as then? What is implied, in this connection, in the word "developed?" I would simply say, first, that not the slightest trace of the action of light would have been visible upon the plate just exposed, upon either end, even upon the closest and most careful examination. But, secondly, in response to proper chemical tests, called developers, an invisible effect, sometimes called a latent effect, or image, will become visible, that is, of course, if it has been produced.

It is the possibility of the production of such an invisible latent, but developable effect of the action of light that constitutes the grand discovery of Daguerre, a discovery that may well be regarded as the initial fact of modern photography, and one that renders Daguerre the central figure around which the facts in photographic history most naturally group themselves. In this statement I have no disposition to deny or detract from the merits of other investigators in this direction. After Scheele almost every chemist and physicist of eminence had experimented to some extent with compounds sensitive to light. Among them Davy, Wedgewood, Wollaston, Herschell, Niépce, Talbot and many others whose names we cannot even take time to recall. Many of these, or most of them indeed, worked much more scientifically than Daguerre; many of them had a great measure of success in some directions; but all efforts to fix an impression of the image formed in the camera obscura upon a sensitive surface were practically failures up to the time of Daguerre's discovery. It may, therefore, be allowable to give a more detailed account of it, in order to emphasize its historic prominence.

Daguerre was a scene painter in Paris, and an artist of considerable merit, and highly successful in his profession. About 1824 he was first seized with the infatuation to fix permanently the evanescent pictures of the camera, which he employed to assist him in his profession. Nothing already accomplished in that direction seems to have incited him, or encouraged him. How much he even knew of what had been done cannot be accurately stated, but this much can I think be said with certainty, that nothing already accomplished indicated in the remotest degree the possibility of discovery in the direction finally taken by him.

But now I am notified that our exposed plate is ready to be exhibited upon the screen, and we will have the opportunity to compare the effects of the red and blue ends of the spectrum upon it. We see in the picture upon the screen that there has been an impression upon that end of the plate. I do not recognize the picture* but what it may be matters not, it is the fact that an impression has been produced, that is the all-important fact for us. The photographic assistant informs us that this is the half exposed in the blue end, and now as he passes the other end into the lantern the blank upon the screen shows the absence of effect by the red rays.

[Thus Fig. 1 represents our stereoscopic negative, in which a diagram is substituted for the sake of simplicity, for the view from nature, and in Fig 2 we have the resulting positive at the blue end, and the blank at the red end.]

So far our experiment yields results identical with those of Scheele's with silver chloride. But these effects, as I have already stated, were invisible when the plate left us; they have only put in an appearance under a treatment called *development.* And now let us return to the history of the discovery of this developable effect. Some portions of it remind us of those little bits of embellishment often thrown around the history of science, as well as civil history. I would hesitate to give it had I not strongest ground for belief in its authenticity. No alchemist had ever gone to work at a more unpromising task than that Daguerre had imposed upon himself. As years rolled on the passion only took deeper hold upon him. In spite of utter failures and discouragement of all kinds, for years, in loneliness and in secrecy, suspected of mental weakness, even by his wife, he kept on in the same line of experiment. Finally one of those accidents, that only strike men who work their way across their path, brought him most remarkable success. One of his methods, in brief, was to subject polished plates of silver to the vapor of iodine until they became coated with a creamy film of silver iodide, then to expose this surface to the image in the camera; but always without the hoped-for effect. The plates thus exposed, were then stowed away in the rubbish closet until the supply was exhausted. They were then taken out, re-polished and re-exposed in the camera with the same discouraging results. Upon one occasion, on removal of the plate from the rubbish closet, he found upon it, to his great surprise, the very image that had fallen upon it in the camera. He proceeded to investigate. He exposed another plate in the camera and placed it in the closet with a similar result. Then exposing one plate after another in the camera, and each time removing from the closet some article before stowing the plate in it, each time he found upon it the same faithful delineation of his camera picture. At last everything had been removed, and still the exposed plate placed in the closet exhibited the developed image. Some mercury spilled upon the floor of the closet alone remained. The magician was detected. The vapor of mercury developed the invisible or latent image on the exposed

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* It was a negative of Luray Cave, by C. H. James.

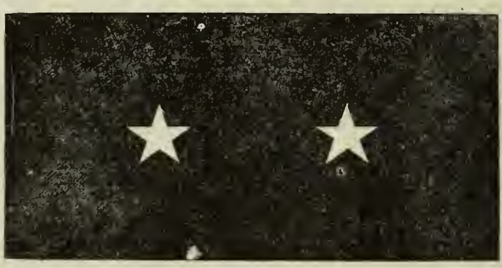
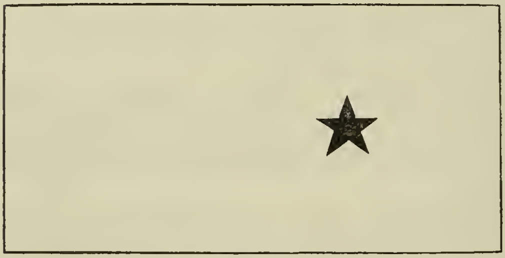


FIG. 1.



R. FIG. 2. B.

iodized plate. For some reason or other, the mercury adhered to the portions acted upon by the light, and in proportion to the action of the light, thus rendering faithfully all the gradation of tones. The excitement in the scientific world upon the announcement of the success was intense. Capital, however, hesitated to patronize the invention; but Arago struck with the exquisite beauty of these first Daguerreotypes, and the promises of the discovery, undertook its advocacy, and the French legislature pensioned Daguerre and his co-laborateur Niépce, that it might present the invention as a gift to the world. The formal anannouncement of the process was made before one of the most brilliant assemblages of the French capital. But it may be asked:—after all, what was there so important in the discovery of an invisible effect that needed development? The great value lay in the rapidity with which this developable effect could be produced. Hours required before to produce the feeblest visible effect were now reduced to minutes, and even seconds. It was permitted to hope that portraits would become possible. The first successful attempts at photographic portraiture were not, however, made by Daguerre, but by that remarkable man, Dr. John W. Draper,* of New York. By his previous careful scientific investigations, he was prepared at once to see the importance of Daguerre's discovery and to utilize it. But these compounds as then produced were comparatively so slow to receive even the latent effect, that the subject was obliged to sit with powdered face in the bright sunshine.

But to return to the spectrum. The recognition of three classes of effects in sunlight is inevitable. Two of these, light and heat, accompanied as they are by corresponding sensations report themselves to us directly. The existence of the third, without any corresponding sensation, we may regard as first established on a scientific basis by the investigations of Scheele, and he also showed that it was not equally distributed throughout the spectrum. Herschell in his investigation of the distribution of heat found, that after the visible spectrum had ceased with the extreme red rays, there were still rays invisible, incapable of affecting the retina, but capable of producing heat, and Professor Langley recently, with his delicate "bolometer," pushing his investigations still further into this infra-red region of the spectrum, has demonstrated the presence of rays where their presence was hardly suspected before, in fact where extra-polation formulæ would not allow them to exist.† So on the other hand Ritter, continuing the investigations of Scheele, found equally invisible rays in the ultra-violet portion of the spectrum, capable in the highest degree of producing chemical changes.

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* "Draper's Sci. Memoirs," p. 215; "Philosophical Magazine," Sept. 1840.

† "Am. Jour. Sci.," vol. xxvii, p. 170, March 1884.

The diagram now upon the screen (Fig. 3) is intended to exhibit the distribution of these qualities of sunlight in the spectrum in a most general way. Although liable to misinterpretation, with care, it will serve a purpose, and will help in emphasizing the direction in which some of the most recent advances in practical photography have been made. The curved line *III* shows the variation in the intensity of the heating effect, with its maximum in the dark infra-red region; the curved line *I*, shows the same for the luminous or visual effect, with its maximum near the line *D*, in the yellow, and gradually fading out at the limits of the visible spectrum; the curve *II*, is intended to show the distribution of actinism, with its maximum in the violet and extending far beyond into the ultra-violet dark space, but feeble in the visible portion, and almost wanting in the yellow, about the line *D*. This last may be regarded as correct for the compounds that have been and are yet generally used in photography; just as Scheele demonstrated for the direct effect upon the silver chloride, and as we demonstrated a few moments ago for the developable effect upon others. We have in consequence become habituated to speak of violet as actinic rays, and of the red and yellow as non-actinic. We will find how incorrect this is.

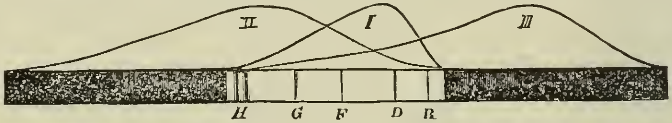

FIG. 3.

It was demonstrated many years ago by Dr. Draper, among others, that the effective rays in producing those changes upon which vegetable growth depends are not the violet, or ultra-violet, not the photographic rays, but rather the yellow and orange. Even the compounds of silver in common use, on more careful investigation, display different degrees of sensitiveness to the different colored rays. The diagram now upon the screen, after Capt. Abney (Fig. 4), exhibits this fact in regard to the three closely related compounds, silver chloride, bromide, and iodide, the basis of modern photography. The upper diagram, you will recognize as a reference diagram of the solar spectrum, with the principal Fraunhofer lines, and the corresponding colors indicated beneath

Now following the curves indicating the variation in the intensity of effect upon the compounds, the maximum for each seems to be about at the same point in spectrum, about the line *G*, in the blue. But the variation in intensity from this maximum point is different in each case. On the iodide the diminution is very rapid toward the violet, as shown by the abrupt fall of the curve, whilst on the bromide it is very gradual, the colors from *b* to *H*, from green to violet, impress the bromide more nearly equally, and would therefore be much more uniformly rendered in a photograph upon it. But there is another fact equally apparent in the diagram, the range of effect upon the bromide is greater, as is shown by the extent of the curve beyond *b* on the one hand, and *H* on the other. The bromide would receive, then, impression from colors to which the others would be insensitive. But in spite of these marked differences, the rays toward the blue end are in each case the most effective. It seemed to be generally accepted for a long time that whilst an actinic effect of some degree could be produced throughout the whole visible spectrum, that whilst every ray that can affect the retina is also capable of affecting to some extent these sensitive compounds, still the power to produce chemical change resided, for some reason, in the highest degree, for all compounds, in the more refrangible rays toward the violet.

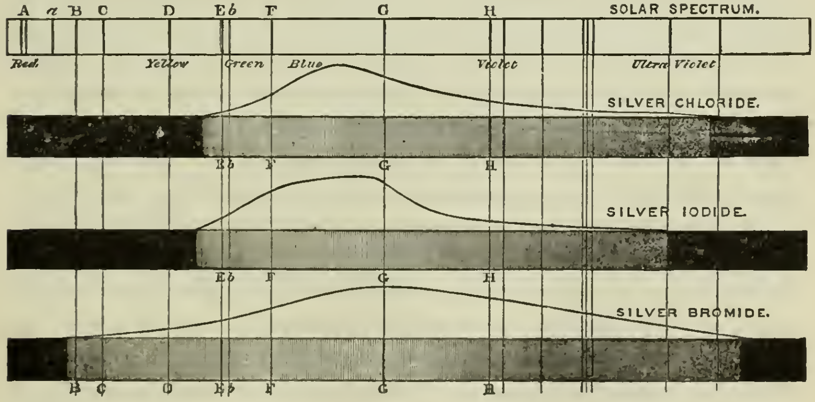

Fig. 4.

It seemed to be accepted almost as inevitable, that photography could never render faithfully the luminous or visual effects, the intensity of effect upon the retina, of the different colored portions of an object, by proper shades in monochrome. That, for example, in a photograph of an orange tree, its bright yellow fruit, and its dark green leaves, would both be represented as equally dark, because practically equally non-atinic. So in the investigation of the spectrum by the aid of photography, that the actinic end alone would impress itself with all its details, and that for the infra-red, other modes of investigation would have to be resorted to. Directed by a theory, which we will notice presently, Dr. H. W. Vogel,* of Berlin, succeeded, in 1873, in increasing the sensitiveness of these same common compounds of photography to the less refrangible, non-actinic rays. The process is so simple that it surprises. The light that acts chemically is the light that is absorbed by the particular substance, or, light to produce an effect must be absorbed. This condition was first enunciated and demonstrated by Dr. Draper.† Dr. Vogel stained the sensitive film with some transparent dye. That certainly meant absorption of certain selected rays; of the red, if he pleased so to select the dye. Just as the blue glass, which I now place in front of our arc-light, absorbs certain rays, and cuts them out of the spectrum upon the screen, as you see. (See Fig. 7.) He reasoned, then, that these absorbed rays may become photographically effective, and produce, or increase the intensity of, the impression upon the sensitive compound. If red was absorbed the effect of the red portions of an object would be heightened, and approach, or perhaps equal, the effect of other more directly actinic rays; or the point of maximum effect in the spectrum might be changed, and rays previously altogether non-actinic, even in the infra-red, might be made to report themselves upon the photographic plate. It is not necessary to indorse this theory. There are, it must be confessed, grave objections to it. But the accomplished fact must be recognized by all, that stained films sensitive to rays commonly regarded as non-actinic have been produced. Capt. Abney,‡ by a different method, has also modified the bromide of silver, without changing its chemical composition, so as to render it impressible by the red rays, and has succeeded in photographing the red end of the spectrum. But Dr. H. W. Vogel,§ within the last few months, as the result of continued investigation in his original direction, has achieved a success in practical photography which, in its results, seems only second to that of Daguerre, and which leaves nothing great beyond to be accomplished, except the fixing of the colors themselves. A new word is necessary to describe this phase of the art. The term isochromatic photography has been introduced. A photography that will give you a picture of the orange tree with its yellow fruit and green leaves, not in their natural colors, but what is almost as desirable, in their natural shades, according to their luminous or visual intensity, the intensity of the impression they make upon the retina of the eye. A photograph of an oil painting, by the old process, could not but be unsatisfactory. Its yellows would be dark, its warm reds would be black, whilst its deep blues, that hardly affect the eye, would present themselves among the high lights of the picture. By the isochromatic process the reds, yellows and blues of the painting are all represented by shades that faithfully represent their luminous or visual effect. An artist whose pictures have been copied by it expresses himself as fully satisfied with the results, which is certainly a very valuable indorsement. Prof. Vogel claims to be able to produce eightfold the effect by yellow light that is produced by blue light. From the dye employed it is spoken of as the azaline process. What an advance since the days of Scheele, or even of Daguerre !*

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* See foot-note p. 355.

† "Draper's Sci. Memoirs," p. 230; "Philos. Mag.," Sept., 1841, p. 435.

‡ "Chem. Effect of Spectrum." Eder, p. 49.

§ See foot-note p. 355.

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* The term orthochromatic has been proposed by Dr. Eder, and is growing into use, instead of isochromatic, since it is equally descriptive of the peculiarity of the new process, and is free from confusion due to previous use in a different connection. The increasing interest in this process, and its expansion into a commercial one, for orthochromatic plates are advertised for sale, call for a somewhat fuller notice in regard to it. The credit of having directed investigations into this channel unquestionably belongs to Dr. Vogel. In 1873 (*Philadelphia Photographer*, vol. ii, p. 25, Jan., 1874; *Photographische Mittheilung*, 1873; *Photographic News*, 1874), in experimenting upon alkaline development on silver bromide dry plates, with the spectrum, he found in certain cases unusual sensitiveness to the so-called non-atinic rays. By careful investigation he traced this to the preservative, or other coating of the plate. He had previously enunciated as a law that a sensitizer should be capable of acting as an absorbent of the liberated halogen, and, at the same time, of the light which acts photographically, or, that chemical and optical absorption should accompany each other. Directed by this, by dyeing the film with coraline, he produced plates sensitive to yellow, and, by the use of an aniline-green, plates highly sensitive to red, and concluded that silver bromide could be rendered sensitive to any color. A picture of a blue ribbon on a yellow ground, which by the ordinary process was white on a dark ground, by his process was dark on a light ground. It was necessary to put a yellow glass in front of the lens to tone down the blue, otherwise, if both colors were of equal actinic effect, no

[In the absence of an illustration by Dr. Vogel's process, we are fortunate to have placed at our disposal, since the delivery of the lecture, one by Mr. F. E. Ives of Philadelphia, by his myrtle-chlorophyl

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contrast would have been obtained. In these earlier cases sensitiveness to some particular selected color seems to have been secured rather than equal sensitiveness to all colors. Eosine, suggested afterward by Major Waterhouse, was employed with better success, and Dr. Vogel's continued investigations led to his perfected isochromatic process, in which azaline was employed, in 1884 (*Philadelphia Photographer*, Aug., 1884, p. 251; *Id.* Sept., p. 284). Results by this process of the most varied character on exhibition at the New Orleans International Exhibition are pronounced "marvelous" (*Photo. Times*, Feb. 27, 1885). The announcement of the effect of dyes for this purpose by Vogel was followed by experiments in the same direction by Abney, Waterhouse, Lea and others, and whilst his theory of optical sensitizers was not accepted, nor in all cases could the precise results obtained by Vogel be reproduced, the demonstration of the possibility of isochromatic effects in this way is conceded to him. Dyed films were undoubtedly suggested and used by M. Carey Lea prior to their employment by Vogel (*Anthony's Phot. Bulletin*, Jan. 10, 1885, p. 6; *Silliman's Am. Jour. Sci.*, Jan. 1885, p. 53), but for an entirely different purpose (the prevention of blurring), and without noticing any sensitizing effect to non-atinic rays, if any occurred, and without even hinting at any such possible effect of the dye. It has recently been shown by Lea (*Ibid.*) that the haloid salts of silver are capable of forming compounds with some coloring matters similar to lakes, by use of which plates sensitive to color may be prepared. This seems to be in accord with Abney's theory, that the increased sensitiveness to color is due to the formation of compounds in Vogel's experiments (*Chem. Effects of Spectrum*, Eder, p. 39). In 1879, F. E. Ives, of Philadelphia (*Philad. Photographer*, Dec., 1879, p. 365), published a process in all its details, in which chlorophyl obtained from the leaves of the blue myrtle was employed as the dye, and a cell with glass sides containing a solution of bichromate of potash was substituted for the yellow glass of Vogel. The former has the advantage that the strength of the solution can be readily adapted to the quality of the plate and the character of the subject. He lays great stress upon the chlorophyl from this particular plant, and prepared according to his method, and claims that it was the first perfected isochromatic process, and even unequalled in its results by Vogel's azaline process, which it antedates several years. The specimen by his process herewith presented (see frontispiece) certainly exhibits wonderful capabilities of the process. Becquerel, in 1875 (*Chem. Effect of Spectrum*, Eder, p. 41; from *Comp. Rend* , vol. lxxix, p. 189), found that chlorophyl acted as a sensitizer to the non-actinic rays. Isochromatic plates by any process are slower than ordinary plates, and the yellow screen seems necessary to tone down the blue, but they are susceptible of many applications peculiarly their own. They have been suggested for copying old manuscripts as well as oil paintings.

process first published in 1879,* and in which we are at a loss which to admire most, the isochromatic effect, or the exquisite photo-typographic prints, made by the well known process of the same gentleman. The subject was a highly colored chromo-lithograph of a lady, wearing a bright scarlet hat with purple feather, a yellow-brown cape, and a dark-blue dress. The effect of the non-actinic colors has been even exaggerated, purposely, to demonstrate the capacity of the process.]

What is the nature of the changes produced by light? Scheele demonstrated, if he did not express it in the terms that we employ to-day, that silver chloride was decomposed by the action of light, that its rays dissected off atoms of chlorine, or to use a more modern term that it was a case of chemical *dissociation*, and that a lower chloride of silver was formed of a violet color. With reference to the effect, subsequently discovered, upon bromide and iodide of silver, opinion was at first inclined to call the change a physical one, and not chemical, a change in the arrangement of the molecules of the substance, in their relations to each other, not a change in their kind; afterward opinion was divided between physical and chemical change, whilst to-day there is general agreement that the change is essentially the same as that experienced by the chloride, namely chemical dissociation or decomposition, that bromine and iodine are separated. The difference between the chloride and iodide, or bromide, lies in the fact, also first clearly stated by Professor Vogel,† that the latter demand, as a favoring condition, that something should be present to dispose of, to absorb, the liberated iodine or bromine.

Indeed iodide of silver, without the presence of some such an absorbent, is not acted upon by light, and the bromide but slightly. A photographic collodion plate always contains such an absorbent in the free silver nitrate solution adhering to it. If an iodized sensitive plate is thoroughly washed, it becomes insensitive, but if now it be dipped into a solution of tannin it becomes sensitive, even when dried. Tannin acts as an organic absorbent of iodine. Photographic collodion dry plates rest upon the presence of such chemical absorbents, as sensitizers, and which from their action we called *chemical sensitizers.* To the sensitizers, previously described, that render isochromatic photography possible, the dyes applied to the film, the name *optical sensitizers* has been given by Dr. Vogel, on the ground that they do not act chemically, or as absorbents of iodine, or to state him more fully, because there is considerable discussion going on at this point, they do not act exclusively or principally as chemical absorbents, but by reason of their power to absorb particular colored rays, and thus to increase their effect by increasing the quantity, so to speak, of that particular light acting upon the chemical compound with which they are associated.

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* See foot-note p. 355.

† "Photographic News," 1865, p. 209.

I confess there are difficulties, theoretical and practical, in the way of accepting this theory of optical sensitizers, but it does not minify the discovery of Dr. Vogel to disagree with him on this point, and so eminent an authority as Captain Abney rejects altogether the term optical sensitizer, and as already stated, he has succeeded in photographing the red end of the spectrum by modifying the silver bromide. upon an entirely different plan.*

There is another very remarkable actinic effect that calls for a passing notice. It might be inferred, that if the action of light for a short time produces these feeble but developable effects, the action for a longer time would increase the effect, that a photographic plate exposed to a view in the camera would only give a more easily developed impression the longer the exposure. It is true that the number of molecules decomposed is proportional to the action of the light, that light does all the work of decomposition, that one decomposed molecule does not propagate, so to speak, the effect to others, but still it is a fact well known to photographers, and generally called *solarization*, that a reversed effect is produced upon a plate exposed for too long a time; that on such a plate, the sky, for example, the high light of the picture, that should produce the most intense effect, that should darken most under development in the negative, becomes thin and transparent. And in photographing the solar spectrum it is possible to produce these reversed effects, so that the dark lines receive a heavier deposit, and instead of being transparent in the negative, as might be expected, are more opaque than the luminous portions of the spectrum. A slight previous exposure of the plate to diffused daylight, before exposing in the camera, is favorable to this reversion of effect.

We can only say that one explanation of this contradictory phenomenon is, that there is an oxidizing action of the rays subsequent to the first effect of decomposition, and this brings us now to notice a radically different class of effects of light from those that we have been considering. I have here upon the table, protected from the light by a slight covering, a series of little glass bulbs such as I hold in my hand, with tubes at each side, connected with each other by gum tubing, and finally with a glass tube leading out through the cork of a glass flask, or decomposing cell, which contains hydrochloric acid. Into this, through holes in the cork, protected by glass tubes, dip carbon rods, the flask being closed air-tight. The carbon rods are connected with the poles of the battery upon the table. The current of electricity passing through the hydrochloric acid, as is well known, separates the elements of which it is composed, and the hydrogen and chlorine pass out through these bulbs non-combined, but simply mixed as gases, and after a time these bulbs will be filled with a mixture of the gases in the proportions in which they were present in the hydrochloric acid. Now, singular to say, what the electricity has done light can undo, or *vice versa.* I place one of these little globes, containing the mixed gases, with the end of one tube underneath the colored liquid in this little bottle, whilst the other tube is tightly closed. I now turn on this incandescent light near the bulb, the rise of liquid into the bulb shows that the gases have combined to that extent, and that the resulting compound, the hydrochloric acid formed has been absorbed by the liquid. The rapidity of the combination depends upon the actinic intensity of the light. If placed in sunlight, or even the glare of the arc-light, they would combine with explosive rapidity, and we would fail to follow the experiment as we can in this way. Now this combining action of light upon hydrogen and chlorine is distributed throughout the spectrum in the same manner as the dissociating action upon silver chloride. If we could determine the degree of one kind of effect produced by a given light, we would have determined it for the other.

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* Chemical Effect of Spectrum, Eder, p. 49.

I have selected this experiment, and have performed it as I have, to assist in illustrating one of the various methods for measuring the actinic intensity of light. The effect upon the eye, the photometric effect, does not afford any means of judging of actinic effect. As we have seen, the rays that effect the retina have feeble actinic effect; it is in most cases the invisible rays that do the photographic work. Now the quality of sunlight in this respect varies from day to day and hour to hour, as well as with the seasons, with meteoric conditions that do not report themselves to the eye, or to ordinary meteorological instruments. Nothing could be more desirable to those employing this agency, than some method, or instrument rather, by which actinic intensity of sunlight could be readily tested at any time.

That remarkable man, Dr. John W. Draper, of New York, who never simply did a little and suggested a great deal more for some one else to do, as is so often the case, first used this fact of the combination of hydrogen and chlorine under the action of light for actinometric purposes.* He devised an instrument, and made determinations of surprising accuracy, and Bunsen and Roscoe† long afterwards adopted his plan and expanded it so as to establish *actinometry* on a thoroughly scientific basis.

I call your attention now, by way of illustration of one mode of application of these facts, to a piece of apparatus, devised by Dufour,‡ in which this apparent antagonism between the electrical current and actinism is utilized for measuring the latter. In the diagram (Fig. 5)

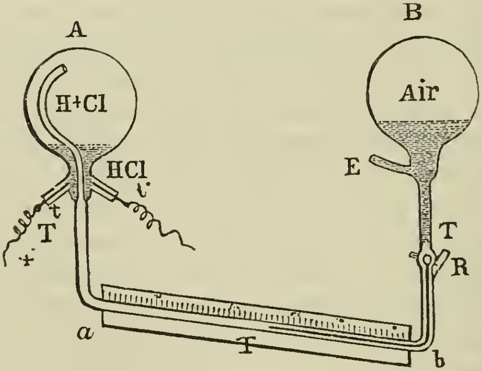

Fig. 5.

A and *B* are glass bulbs connected by a small glass tube *T*, *T*, *T*, which passes up through the neck of *A*, as indicated, and opens into the bulb near the top. This bulb is partially filled with hydrochloric acid, HCl, with a mixture of hydrogen and chlorine gases, $H + Cl$, sensitive to light above. In the other bulb *B*, an equal volume of air is enclosed over sulphuric acid. The stop-cock at *R* being opened, the sulphuric acid will take a fixed position in the horizontal graduated connecting tube, and serve as an index. Now upon exposure of the bulbs to light, a portion of the gaseous mixture in *A*, would combine, and the resulting hydrochloric acid gas formed would be at once absorbed by the liquid, and the sulphuric acid index would move toward *A*. Any disturbing influence of heat upon the experiment is eliminated by the equality of effect on both bulbs. But now, if instead of simply allowing light to produce combination, we at the same time produce a counter effect by means of an electrical current passed through the HCl, by means of small carbon rods inserted through the lateral tubes *t*, *t*, and connected with the poles of a battery, by varying the current until combination and decomposition are equal, the index will be rendered stationary and a comparison of the strength of electrical currents required in two cases to produce this condition will be a comparison of the actinism of the light in any two cases. It is almost needless to remind you that there are many substances adapted to actinometric purposes. Silver chloride paper, such as we used in our first experiment has been employed. Ferric oxalate, which, under the influence of light, decomposes and evolves carbon dioxide, which may be measured or estimated by loss, was also suggested and used by Dr. Draper. But there is still need of a convenient and reliable actinometric method. But in any case it is plain from what we have already said that an actinometer adapted to one set of rays would not be reliable for others; or one that would give the intensity of effect at a given time upon one substance would not necessarily give the effect upon another substance.

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* "Draper's Memoirs," p. 245; "American Jour. Sci.," vol. xlvi; "Philos. Mag.," Dec. 1843.

† "Die Actinometrie, Pizzighelli," p. 13; "Poggendorff Annalen," Vol. c., pp. 43, 481; "Watts Dict. of Chem.," Vol. iii, p. 678.

‡ "Die Actinometrie, Pizzighelli," p. 37; "Photo. News," 1881, p. 158.

We have thus rapidly noticed some of the leading actinic effects of light. How are these effects produced? This question brings us face to face with the other questions: What is the mechanism of light? What is the ultimate constitution of matter? We have no difficulty in accepting the undulatory theory of light so clearly set forth by Sir William Thomson* a few days ago. Let us assume in round numbers that 800 million million of undulations per second of the hypothetical ether, that pervades all space and all matter, produces the sensation of violet and 400 million million produce that of red; that beyond violet there are other undulations still more rapid, and below red slower ones, neither of which report themselves to us as light, that do not affect the retina of the eye. These wavelets beat upon the sensitive compounds we have been considering; these are composed of groups of atoms called molecules; these molecules are shaken until each one looses an atom or two, new groups of atoms, new molecules are formed, that is a new substance is formed. It may have a color different from that of the original, perhaps, as sub-chloride of silver, or different attractive properties, as the changed iodide for mercury in Daguerre's process, or for silver just reduced from its solution as in the ordinary collodion process. We are surprised sometimes at the rapidity of the action of light at the so-called instantaneous photographic effects; the pictures of animals in motion, of bombs bursting in air, etc. Let us look at these in the light of our theory, and may be we will find that after all these effects are rather slow. I now call your attention to a photograph, upon the screen, of sparks of a Holtz machine (Fig. 6.). I have selected this because these sparks are of shorter duration than that any instantaneous drop or slide could be made to give. They impressed themselves upon an ordinary collodion plate in the camera as they passed. Suppose we assume $\frac{1}{20000}$th of a second as the time, and we will certainly be within bounds. That is a fraction difficult to comprehend. Sir William Thomson* told you a few days ago, that it was easy to understand large numbers, just as easy to comprehend a million-million as a million, that it is the negation of infinity that is difficult to understand. But this small fraction will trouble us. Our mental dividing engine fails in performance as we work toward zero. The twenty-thousandth of a second is so small that it eludes our mental grasp. Now astronomers when wrestling with celestial distances frequently resort to artifices to bring them within the range of comprehension. They fire imaginary cannon balls at the sun, and convert the vast distance into time by calculating the duration of its flight at its greatest

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* Lecture on "Wave Theory of Light," Academy of Music. *Vide* this JOURNAL, Nov. 1884.

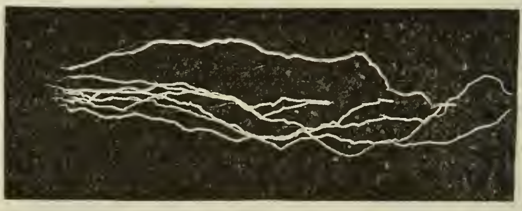

Fig. 6.

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* Lecture at Academy of Music, Sept. 29th. *Vide* this JOURNAL, Nov. 1884, vol. cxviii, p. 327.

velocity; again they build imaginary railroads to the fixed stars, and calculate the generations that will be born and perish before the train reaches its destination, or to bring the matter down still nearer the ordinary apprehension, they calculate the fare and state it in terms of the national blessing as a unit, and thus put it on a dollar and cent basis, and we allow ourselves to be persuaded that we have mastered the difficulty. Now without resorting to any artifice, without changing the character of our phenomenon, but simply looking at it from another point of view, let us regard the effect as a space effect of light instead of a time effect. Light has a velocity in round numbers of 190,000 miles per second, that would be 190 miles in one thousandth of a second, 19 in one ten-thousandth, or say 10 miles in our $\frac{1}{20000}$th of a second. Ten miles of light drive in upon our plate in that time; or if we held the corpuscular theory of light of Newton, a chain of these little pellets ten miles long would have delivered themselves upon the sensitive surfaces. Ten miles is comprehensible, one mile is, so that we could easily conceive of an effect in one-tenth of the time allowed to our electric sparks. But let us take another look at it. Light is not corpuscles but undulations, tiny wavelets, ripplets of ether, 800 million-million in a second for violet, a number we can easily understand, as Sir William Thomson has told us; that would make 800 thousand-million in one thousandth, eighty thousand-million in one ten-thousandth, or 40.000 million impulses striking upon our sensitive molecules in our $\frac{1}{20000}$th of a second. Surely that number should produce an effect. We can readily conceive that one thousand-million wavelets might produce an appreciable effect. They would only represent one eight-hundred-thousandth of a second, say one millionth of a second. That would seem, then, to be ample time to produce a photographic effect. Theoretically, we would hardly fix it as a limit of photographic sensitiveness, an encouragement certainly to instantaneous photography; for although the light of the sparks was and intense, the waves sent out by it have great amplitude, the plate that they have impressed is comparatively insensitive, not such as we would employ ordinarily to receive an instantaneous impression.

But it may be said these wavelets are very small, but so are the portions of matter upon which they operate, molecules that not only elude our grasp, but almost defy calculation, and still smaller atoms, the components of these molecules. The action of these waves of light upon matter may not, unfitly, then be compared to that of the waves of the ocean upon the shore. But to get some notion of how these wavelets may act, let us resort to a coarse mechanical contrivance that will exhibit transfer of energy. These two balls, or pendulums, are connected, by suspension, on this wire stretched across the stage. I cause the one to vibrate, you notice that the other ball soon begins to vibrate, and also that its motion increases. Now if you turn your attention to the first, you will notice that its motion is decreasing at the same rate that that of the second is increasing. Now the second has acquired all the motion of the first, the first has ceased moving, and now the motion begins to be returned by the second to the first. I have arranged these balls so that either is, so to speak, in a peculiarly receptive condition with reference to the motion of the other. They are pendulums of equal lengths, of the same periods of vibration. I now change the length of one, by sliding the second ball upward on its supporting cord. I vibrate the first again, the second as you see takes motion again; the first looses, but for a much shorter time, and in a much smaller degree. Our second ball fails to take all the motion from the first. It is not as receptive as it was before. By similar experiments with this cord, containing two balls, by varying the positions of the balls, we see that there is a jarring of the combination, a movement very dissimilar to that of our two balls at first.

Now a luminous body transmits energy through the ether as a medium, as these balls do through the wire. The molecules of matter, composed of atoms of different kinds, may be in a receptive condition for vibrations of ether of a certain frequency, or they may be jarred, as it were, by these vibrations; atoms, or even groups of atoms, within the molecule may recognize their periods of vibration, and take up motion to such a degree as even to be thrown out. We can thus conceive of many ways in which molecular disruption could be brought about, which would mean chemical change.

But there is another phenomenon, beautiful in itself, and not only closely related to the subject in hand, but that seems to form a sort of a stepping-stone from this gross mechanical illustration to the actinic effect upon molecules. I have said that in this spectrum on the screen, far beyond the violet, there is a region of chemical activity but of darkness, where the photographic plate is impressed long after the retina ceases to be affected. Now if I were to pass out into this dark ultra-violet space, this paper, coated with sulphate of quinine, or other suitable substance, it would become visible, would *fluoresce*, would take up these rapid vibrations of ether, and in some way render them visible, or, to express it better, would cause them to produce a visible effect.

Without taking time to perform the experiment in this way, because from the feebleness of the light it would be unsatisfactory to you, I will get an abundance of these rays by another method. This blue glass, that absorbs almost totally the other rays, allows these ultra-violet rays to pass. As I insert it in the path of the light that passes through the prism you see what portion of the spectrum it transmits. I now place this glass, before the arc light (by opening a side door of the lantern), and it casts only a deep blue, feebly luminous illumination upon the objects behind us. Now, whilst Mr. Knapp holds the blue glass in position, you notice that this white cardboard appears of a deep, feebly-luminous, blue. I now dip my brush into a solution of sulphate of quinine, and as I draw upon the card with the brush, you see how the tracings of the brush spring out in beautiful visible lines upon the dark-blue background of the card. The quinine solution reveals the presence of these ultra-violet rays; it somehow drags these rays down from the invisible into the visible portion of the spectrum, brings them within the range of retinal effect.

But now, what is equally surprising, though on reflection it is what we should expect, when the quinine brings these rays within the range of vision, it in so far removes them from the actinic field. In so far as they are made to affect the retina, in so far they cease to affect the sensitive plate. A photograph of this card, as it now appears in this ultra-violet light, with its luminous tracings of the brush, would give you dark letters upon a white ground, just as if drawn with ink; not as dark as with ink, but still deeply shaded, as they have been photographically degraded below the ultra-violet ground on which they are formed.

We have upon the wall much larger designs, kindly placed at my disposal by Professor Henry Morton, so well known in your city, of the Stevens Institute, of Hoboken. The two floral designs upon my left are of especial interest. The one is traced with thallene, a fluorescent substance, first isolated by Professor Morton; the other is formed of yellow paper. In the light of our electric arc lamp the paper design is most decided. We now illuminate with our ultra-violet light, by interposing the same blue glass; the thallene design springs out in beauty from the dark ground, by degrading the light into the region of vision; the paper design becomes almost invisible, having only the feebly luminous blue light to reflect. Briefly, what is the explanation of this phenomenon, and what its bearing? The investigations of it by Professor Stokes are classical. His figure will help us. Imagine a number of vessels at rest upon a perfectly quiet sea. Suppose a series of waves, without any wind, originated by a storm afar off, propagated by the water, reaches the vessels; these will begin to swing back and forth, but in their own time, not necessarily the periodic time of the impinging waves. They would become new wave centres, sending out waves of their own period. So, in fluorescence, the molecules of sulphate of quinine, for example, struck by the rapid ethereal wavelets of the ultra-violet, begin to swing; but they vibrate in slower periods, because it is their nature, and originate waves of ether of their own rate, slower than the 800 million-million per second of the ultra-violet, but more rapid than 400 million-million, the limit of the visible spectrum at the other end. It originates, in other words, visible light, the violet is not changed into blue and yellow, it has simply produced an effect, and in so doing has ceased as such. The light that produces fluorescence is just as truly absorbed as that that produces chemical effect.

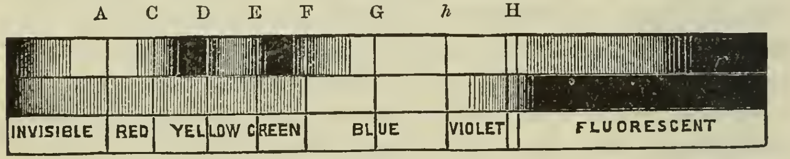

Fig. 7.

By comparing, in the diagram on the screen (Fig. 7), the absorption spectrum of the cobalt glass employed (1), and that of the sulphate of quinine (9), you will see that what the cobalt glass allows to pass beyond the violet, the quinine absorbs, and in absorbing fluoresces. We have, then, in this phenomenon a stepping-stone between our pendulum experiment and chemical effect. We are here dealing still with molecules, but molecules taking motion from each other as the pendulums did, but their atoms still hold together in the same molecular groups in spite of their motion, the sulphate of quinine still remaining quinine. The effect seems just short of chemical effect. This subject of fluorescence, and the closely related one of phosphorescence, is so attractive that it would hold us; but it has served our purpose for this evening; and, as we have already much exceeded our time, we must leave this subject of light in its chemical relations, with many points of interest untouched, and with thanks for your attention to the necessarily hurried, and incomplete presentation of so important a subject.

ISOCHROMATIC PHOTOGRAPHY.*

By Fred. E. Ives.

It is well known that the ordinary photographic processes do not reproduce colors in the true proportion of their brightness. Violet and blue, photograph too light; green yellow, orange and red, too dark. For a long time it was believed to be impossible to remedy this defect; and even when it became known that bromide of silver could be made more sensitive to yellow and red by staining it with certain dyes, the subject received very little attention, because it was also known that the increase of sensitiveness was too slight to be of practical value in commercial photography.

Dr. H. W. Vogel, who was one of the first, though not the first, to devote attention to this subject, announced, in 1873, that he had succeeded in making a yellow object photograph lighter than a blue or violet one, by using a silver-bromide plate stained with coraline, and exposed through a yellow glass. The plate showed no increased sensitiveness to red, and the experiment, although of considerable scientific interest, did not indicate a practically useful process.

In the spring of 1878 I became interested in this subject, and tried to discover a method of producing plates which should be sensitive to all colors, and capable of reproducing them in the true proportion of their brightness. I commenced by trying nearly all the color sensitizers which had already been suggested, in order to learn which was the best, and then, if possible, *why* it was the best, as a guide to further research. Chlorophyl was the only thing I tried which was sufficiently sensitive to red to offer any encouragement in that direction; but the solution which I obtained was weak and unstable, and far from being a satisfactory color sensitizer. Hoping to obtain a better solution with which to continue my experiments, I made extracts from many kinds of leaves, and found that a solution from blue myrtle leaves looked better and kept better than any other, and when it was applied to the silver-bromide plates they became remarkably sensitive, not only to all shades of red, but also to orange, yellow and green. By placing in front of the lens a color-screen consisting of a small glass tank containing a weak solution of bichromate of potash, to cut off part of the blue and violet light, I obtained, with these chlorophyl plates, the first photographs in which all colors were reproduced in the true proportions of their brightness. But my chief desire at that time was to realize a method of producing from any object in colors a set of three negatives, in one of which the shadows should represent the blue of the original, in another the yellow, and in another the red, in such a manner that transparent pigment prints from these negatives—blue, yellow and red—would, when superimposed on a white surface, represent not only the lights and shadows, but also the colors of the object. This had already been attempted by others, who failed because their plates were not sufficiently sensitive to red and yellow.

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* Read at the stated meeting of the Franklin Institute, March 18, 1885.

Having succeeded perfectly in my undertakings, I published my discovery in 1879,* explaining how to prepare and use the chlorophyl plates, in connection with the yellow screen, for the purpose of securing correct photographs of colored objects.†

So far as I know, nobody tried the process. Nearly five years later Dr. Vogel announced that, after eleven years of investigation, he had at last realized a successful process of this character, and that this new process of his, was the "solution of a problem that had long been encompassed with difficulty." This publication attracted a great deal of attention, and gave me occasion to again call attention to my process,‡ and point out that it was not only the first practical solution of this problem, but the only truly isochromatic process ever discovered. Dr. Vogel's new process was not only no better in any respect, but the plates were insensitive to scarlet and ruby-red, and therefore would not photograph all colors in the true proportion of their brightness.

My method consists in treating ordinary collodio-bromide emulsion plates with blue-myrtle chlorophyl solution, exposing them through the yellow screen, and then developing them in the usual manner. The emulsion which I have employed is made with an excess of nitrate of silver, which is afterward neutralized by the addition of chloride of cobalt; it is known as Newton's emulsion. I now prepare the chlorophyl from fresh blue-myrtle leaves, by cutting them up fine, covering with pure alcohol, and heating moderately hot; the leaves are left in the solution, and some zinc powder is added, which helps to keep the chlorophyl from spoiling. I have a bottle of this solution which was prepared about six months ago, and now appears to be as good as when first made.* A glass plate is flowed with the emulsion, and as soon as it has set, the chlorophyl solution is applied for a few seconds, after which the plate is washed in pure water until smooth, when it is ready for exposure.

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* *Philadelphia Photographer*, December, 1879, p. 365.

† I intended this publication to be a very full and explicit one, and it was sufficiently so to be perfectly understood by most who saw it; but some may think I did not sufficiently emphasize the importance of using the particular kind of chlorophyl which I mentioned. In a brief communication to the editor of the *Photo. News*, in 1883, I described some experiments with eosine as a color sensitizer, and then called attention to the superiority of blue-myrtle chlorophyl for this purpose, stating that I had not been able to secure such results with any other kind of chlorophyl, and that a fresh solution from fresh leaves must be used to secure the greatest possible degree of sensitiveness. See *Photo. News*, Nov. 1883, p. 747.

‡ *Photo. News*, London, September 5, 1884, p. 566, and *Year Book of Photography* for 1885, p. 111.

My color-screen consists of a small plate-glass tank, having a space of $\frac{3}{16}$ of an inch between the glass, filled with a solution of bichromate of potash about one grain strong. I place the tank in front of the lens, in contact with the lens-mount. The advantage of this tank and solution is that it can be more easily obtained than yellow plate glass, and the color can be adjusted to meet any requirement.

The plates require about three times as much exposure through the yellow screen as without it, and may be developed with the ordinary alkaline pyro-developer.

In order to illustrate the value of this process, I made two photographs of a highly-colored chromo-lithograph, representing a lady with a bright scarlet hat and purple feather, a yellow-brown cape and a dark-blue dress. One, by the ordinary process, represents the blue as lighter than the yellow-brown, the bright scarlet hat as black, and the purple feather as nearly white. The other, by the chlorophyl process, reproduces all colors in nearly the true proportion of their brightness, but with a slight exaggeration of contrast produced purposely by using a too-strong color solution in the small tank. These photographs are herewith reproduced. (See frontispiece.)

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* I originally recommended chlorophyl extracted from dried leaves, because I had not yet learned how to preserve the solution for more than a few weeks,—and at some seasons it would be difficult, if not impossible, to obtain fresh leaves. The tea organifier which I recommended is also a color sensitizer, and when it is used in connection with the chlorophyl from dried leaves the plates are as sensitive to red as can be safely prepared and developed in the light of an ordinary photographic "dark-room." Plates prepared with chlorophyl from fresh leaves do not require treatment with the tea organifier to secure this degree of sensitiveness. Recently I have used the tea organifier and some other sensitizers, in connection with the solution from *fresh* myrtle-leaves, and in this way have produced plates having such an exalted color sensitiveness as to be unmanageable in ordinary "dark-room" light. Possibly, such plates might be prepared and developed in total darkness, by the aid of suitable mechanical contrivances, but I am not sure that they would work clear even then, because they appear to be sensitive to heat as well as to light.

I also made two landscape photographs, one by the ordinary process, and the other by the chlorophyl process, exposing them simultaneously. In the ordinary photograph, distant hills are lost through over exposure, yet the foreground seems under exposed, and yellow straw stacks and bright autumn leaves appear black. In the chlorophyl photograph, the distant hills are not over-exposed, nor is the foreground under-exposed; the yellow straw-stacks appear nearly white, and bright autumn leaves contrast strongly with the dark green about them.

To test the relative color-sensitiveness of plain emulsion plates, plates stained with eosine, and plates stained with the blue-myrtle chlorophyl, I exposed one of each kind through the same yellow screen, giving each five minutes exposure, on the same piece of copy, which was the chromo-lithograph already described. The plain emulsion plate showed only the high lights of the picture, after prolonged development. The eosine plate was under-exposed, but brought up everything fairly well except the scarlet hat, which came up like black. The chlorophyl plate was over-exposed, brought out all colors better than the eosine plate, and gave full value to the bright scarlet of the hat, the detail in which was beautifully rendered.

Dr. Vogel advanced the theory that silver-bromide is insensitive to yellow and red, because it reflects or transmits those colors; and that it becomes sensitive when stained, because of the optical properties of the dyes. He afterwards admitted that only such dyes as are capable of entering into chemical combination with the silver-bromide proved capable of increasing its sensitiveness to color, but he held to the theory that the optical properties of the compound were the cause of its color-sensitiveness.

I have shown that the color-sensitiveness can be produced by treatment with an organic compound which has none of the optical properties characteristic of dyes; and that chlorophyl, which absorbs only red light, greatly increases the sensitiveness also to yellow and green.

There is, therefore, good reason to doubt if the color-sensitiveness is ever due to the optical properties of the dye or combination.

Attempts have been made to produce isochromatic gelatine dry plates which, while many times more sensitive to white light than my chlorophyl plates, shall also show the same relative color-sensitiveness. Such plates would be very valuable but for one fact; it would be necessary to prepare and develop them in almost total darkness. Gelatine bromide dry plates extremely sensitive to yellow, but *comparatively insensitive to red*, might be used to advantage in portrait and instantaneous photography, because they could be safely prepared and developed in red light; but when truly isochromatic photographs are required, the time of exposure must be regulated to suit the degree of sensitiveness to red, which cannot safely be made greater than I have realized with my chlorophyl process.

INTERNAL TEMPERATURE OF THE SUN.—The various methods which have been proposed for determining the temperature of the sun have only referred to the superficial temperature, or that of a shallow depth in the photosphere, since the experiments have been limited to the light and heat which proceed from the photosphere. Some observers have supposed that the temperature does not exceed 1,500°C. (2,732°F.); others, Father Secchi among the number, suppose that the temperature exceeds 10,000,000°C. Hirn gives reasons for believing that the former figure is ten or fifteen times too small, while the latter is very much too great. He has devised an apparatus which he hopes will enable us at least to determine the lowest limit of admissible temperature, and which would probably already have given useful results, if his labors had not been unexpectedly interrupted. Since the light and heat at the surface of the photosphere emanate from solid particles, which are continually precipitated, and incandescent gas, the temperature of liquefaction and volatilization of those particles must be the superior limit of the superficial temperature. Judging from our knowledge of melting temperatures, all chemical combinations would be broken up, and all solid bodies would be vaporized at temperatures between 50,000° and 100,000°C. According to Faye's views, these solid particles, on penetrating toward the centre of the sun, must be liquefied and volatilized anew. The subjacent gaseous layers must therefore be at a far higher temperature than that of the upper surface. Applying the formula, $v = \sqrt{2gh}$ to the superficial jets of hydrogen by means of the estimated velocities which have been given by Lockyer, Young and others, he concludes that the internal temperature of the sun must be reckoned by millions of degrees.—*Comptes Rendus*, June 2, 1884. C.

FIRE HAZARDS IN TEXTILE MILLS.*

By C. John Hexamer.

When we consider that in the year 1883 about one hundred million dollars' worth of property was destroyed by fire throughout the United States, and, that if losses continue at the present rate, they will this year amount to one hundred and twenty-eight million dollars, we must admit that the study of fires and their causes is of intense interest and of the greatest practical value. For the sums just named are so great that the mind cannot conceive them; it is only by comparison that we can arrive at an approximate idea. Let us suppose a clerk to be counting off single dollar notes for the payment of these losses, and that he could count at the rapid rate of 100 in a minute; it would take him 2·43 years to complete his task, without a moment of sleep or rest. Or suppose I placed one dollar notes representing the amount of this annual fire waste in line lengthwise, edge to edge; it would form a line of greenbacks 7,893,333·3 feet long; or, to express it in miles, a strip 1,494·9 miles in length.

One of our technical papers, in moralizing on the annual fire loss over a year ago, truly said:

> "All of this former huge amount of property has literally been blotted out of existence. Whether the losses were borne by the insurance companies or by individuals, the result is the complete extermination of just so much wealth which was created by human effort and ingenuity. The world is poorer by that amount than it would have been could these fires have been avoided.
>
> "A person who considers these facts and figures thoughtfully must be impressed with the conviction that the existing means of preventing and extinguishing fires are either very inadequate or very greatly neglected.
>
> "The whole matter will have to receive more consideration in the future than has hitherto been given to it. Civilized society, which leans so much upon human industry, cannot afford to permit vast quantities of the fruits of industry to be blotted out every year, when preventives are within reach."

As is the case in other investigations, it is most difficult to discover the origins—used here in its true sense, that is, causes—of fires. Before preventive measures against enemies of mankind can intelligently be undertaken, be they epidemics or dangers of the elements, we must first know the causes which underlie the evil we wish to overcome. But the writer and observer on this subject labor under difficulties which the student of no other subject encounters to a like degree. The student of a new disease may note the symptoms of a great number of cases which he can diligently examine personally; we, on the other hand, receive our accounts from persons who observed what we most wish to know, while intensely excited and frightened, and only rarely do cases occur where any traces of the origin have been left, while it is exceedingly difficult to obtain information from employés, especially from watchmen, which would reflect on their judgment or honesty in performing their duty.

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* A lecture delivered before the Franklin Institute, Dec. 12, 1884.

In order to lessen the number of fires, not so much better means for extinguishing, as better methods of preventing them, are required; and fires can only be prevented by a proper understanding of fire hazards by all classes. While means for extinguishing fires are daily approaching perfection, fire hazards are daily, through new inventions necessitating the employment of dangerous substances and processes, increased, and it is to the discovery of the hazards of every class of risks, and the invention of preventive means, to which the student of this subject must chiefly turn his attention. It is to the study of the fire hazards of a large class—textile mills—to which we turn our attention to-night.

One of the most trustworthy and complete tables, on the origins of fires in textile mills, is that kept by the Boston Manufacturers' Mutual Fire Insurance Company since October 1, 1850, which was furnished me complete up to January 1, 1884, through the kindness of Mr. C. J. H. Woodbury, their inspector. This table includes only establishments insured by that company—the best types of this class. It gives the causes and numbers of fires resulting from them as follows:

Causes.	Number of Fires.
Foreign substances in pickers	165
Friction	187
Spontaneous combustion through oils	115
Matches	52
Lighting apparatus	36
Sparks and defective chimneys	33
Incendiary	20
Spontaneous combustion of dyed cloth or yarn	26
Broken lanterns and lamps	17
Lightning	13

Causes.	Number of Fires.
Fireworks	7
Stoves	4
Pipes and cigars	4
Window glass acting as lens, concentrating the rays of the sun	3
Spontaneous combustion of bituminous coal	3
Electricity from belts	3
Electric light	25
Water inducing rapid oxidation of iron turnings, which set fire to the sawdust mixed with it (One of these was caused by a freshet.)	2
Hot irons	2
Cutting iron hoops on cotton bales with axes, sparks setting the cotton on fire	7
Heat from furnaces	5
Wood in contact with boiler setting	1
Result of boiler explosion	1

[One was caused by a man accidentally dropping an open penknife on a small bunch of cotton card waste, which burst into flames. After the fire was extinguished, a quartz pebble about one-eighth of an inch in diameter was found on the floor; the steel blade, striking this pebble, caused the spark which ignited the cotton.]

Causes.	Number of Fires.
Matches	12
Gas	7
Steam pipes	5
Mice	1
Hot flues	1
Sparks from emery wheel	1
Petroleum	1
Gasoline vapors	2
Breaking of shaft	1

Let us now turn from statistics to a closer inspection of the hazards, beginning with the raw stock in its progress through the mill.

RAW STOCK.

It may be stated, as an almost infallible rule, and I think the experience of underwriters will bear me out, that, other conditions being equal, the fire hazard varies inversely as the quality of raw stock, and therefore, also, inversely with the quality of the manufactured goods; that is, the poorer the grade of raw stock, the greater the fire hazard. It is absolutely necessary for a mill inspector to be conversant with the different kinds of raw stock, and he should be able to make microscopic and chemical tests of the same, in order to determine the exact proportions of mixed stocks for himself, as the statements of the assured may be, and frequently are, incorrect. We will, further on, exhibit microscopic tests, on a large scale, by examining the different kinds of stock, as thrown on the screen by the projecting microscope.

In this section of the country the so-called "mixed" mills are found to a great extent, and these, on account of the greater fire hazard incident to them, are of special interest to us to-night. In its widest meaning, a "mixed mill" is one in which cotton and wool are spun (by which I include the previous processes of picking). The amount of cotton adulteration in the so-called woolen goods depends on the demands of the market for which the manufacturer is working; therefore, the proportions of raw stocks in many "mixed mills" are constantly changing from nearly all wool to nearly all cotton. By wool is meant the animal fibre of that name in any condition, including wool, shoddy, extract, waste, etc.

Cotton, as a rule, comes to the mill in a pure state; but, as in wool, there are different grades to be taken into account, not only from their commercial value, but from their fire hazard in being worked. The most objectionable grade is "damaged cotton," which has undergone partial destruction by fire, and which (in order to conceal the marks of charring) has been dyed with a dark color. Such cotton when run over the cards will create a great amount of fly, and is, therefore, as we shall presently see, much more dangerous than better grades. Dirty cotton has often been the cause of picker fires, and I am informed that bales are sometimes fraudulently loaded with sand and gravel to increase their weight.

As picker fires are generally due to stones, pieces of iron, etc., which, in coming in contact with the whipper, strike sparks, the value of clean, carefully inspected, cotton, from the fire point of view is self-evident, as is also the necessity of better methods and greater care on the part of Southern cotton growers in ginning, baling and transporting it. These desiderata, which could not be impressed upon the planters by way of the head and heart, have gradually influenced them by way of the purse, as they have found that it is commercially more advantageous to place their stock in the market in a clean condition, and they will, no doubt, very soon deliver it to their customers more free from hazardous foreign particles.

Cotton carding waste is sometimes used in low grade mixed mills, and as it is very short fibred, being carded out in the white cotton mill, creates much fly and dirt in working it; and mills using it are very dirty and hazardous. Re-ginned cotton is another low grade, hazardous stock.

Wool is a much safer stock than cotton. Pure woolen mills are not frequently destroyed by causes directly or indirectly resulting from the stock; and pure worsted mills are among our best risks. It is through the adulteration of the wool that fire hazards are created, and in a direct proportion with the amount of adulteration.

Care should be exercised in wool-sorting rooms, as fires have been caused by the ignition of tar-marked fleeces laid on steam heating pipes to soften the tar used to mark the sheep. Mr. C. J. H. Woodbury suggests the following safe and efficient manner of softening the tar:

"A box about eight feet long, two feet wide and six inches deep, is provided with a bottom made of wire gauze of about one-half inch mesh. Under this box is a piece of iron pipe, with perforations upon the upper side, and connected with the steam supply. When this box is filled with fleeces, and the numerous jets of steam blown through them, they are softened much more rapidly than by warming in the usual manner around steam pipes or stoves."

Wool shoddy is a short fibred wool manufactured from rags. The picking of shoddy is very hazardous, and it is generally manufactured in extra mills (shoddy mills), and the stock or yarn sold to others. Where shoddy is made in a mixed mill it greatly increases the hazard, and the greatest care must be taken in the location and construction of the picker room. When used in large quantities in mixed mills it becomes a source of danger from the amount of dirt and fly made in carding. In picking the rags at the shoddy mill, much oil is frequently used on the stock. The kind of oil is of great importance, for if animal oils are used spontaneous combustion of the stock may ensue on being piled in quantity, and if some of the so-called wool oils be used, which are mixtures of animal oil and petroleum, the petroleum vapors arising from it during the process of manufacture may become dangerous. Yarns manufactured from shoddy picked with wool oil sometimes contain enough oil, even when dyed, to become dangerous on exposure to a high temperature in the dry house. The reason for this is that mineral oil will not readily saponify. An emulsion of lard oil and water with a little ammonia is the safest substance to use on wool. Olive oil, which is frequently adulterated with cotton seed oil, should not be used.

Wool Extract is a shoddy manufactured from rags of a mixed stock, the cotton contained in it having been dissolved by dilute sulphuric acid. It has the objectionable features of shoddy.

Worsted waste, when clean from the drawing frames, is a very good stock, as it has been combed, and when not oily is cleaner and safer than raw wool. The so-called woolen noils, which is the soft waste taken from the wool on the combs, is also a good stock but not as good as pure wool.

Silk noils is the waste from the combs obtained in manufacturing spun silk yarns, is but seldom used, and is not specially hazardous.

In the lowest grades of mixed mills, where a cheap carpet yarn is made, hair, jute, flax, hemp, etc., are sometimes used in mixing. These stocks materially increase the hazard of the mill.

As before stated it is important for the insurance inspector and adjuster, not only to be competent to distinguish a good from a poor grade of wool, but also to be able to detect any cotton in woolen goods. This may, by practice, generally be detected at sight, or by the rough test of ignition. Animal fibres when singed give off a smell of burnt feathers, and when ignited in the flame of a candle are almost immediately extinguished, a carbonaceous residue being left; cotton and linen fibres continue to burn, do not give off the smell of burnt feathers, and do not leave a carbonaceous mass when extinguished. Where a little potash may be procured, the best and most reliable test is to place a piece of the goods in a solution of caustic potash; the wool being dissolved, the cotton remaining intact.

Another easily applicable test is that of nitric acid. On boiling tissues in this acid, silk will assume a light yellow, wool a dark yellow color, while flax, cotton and hemp will remain white. If the proportions of the different components are sought, a small piece of the goods is taken, carefully washed, to free it of all grease, and dried; this is then carefully weighed and boiled with caustic soda until the animal fibres are completely dissolved. The lye solution is then run through a filter, while the fibres remaining on the filter are thoroughly washed with water. The loss in weight of the fibres when dried will then give the amount of animal matter.

The best qualitative test is an examination with a good microscope. Under the microscope, as we will presently notice on the screen, cotton has a flowing, twisted, band-like appearance; linen fibres appear as slender cylindrical reeds; wool has a thick circular stalk covered with scales; silk is slender, smooth, and shines brilliantly.

We cannot state too forcibly that the shapes and lengths of the raw stock are of the utmost importance in "Fire Technology," and that the causes of a great number of fires in "mixed mills" may be directly traced to the nature (physical and chemical) of the raw stock used.

Raw wool—although it does not burn readily—is a more unprofitable stock to insure than is generally supposed. There is but a poor salvage on wool. The keratin; the principal part of wool, when wet, ferments and decays, the wool thus becoming worthless. Although a stock of wool may not have been damaged by fire, it may still be a total loss, since the water poured upon it may have caused fermentation to set in. If speedily taken care of and dried, wool may be cured, although it seldom regains its original quality.

Let us now turn to the hazards of *Dyeing and Drying.*

The process may be generally divided into: first, the cleaning of yarn, warp, or raw stock; second, the dyeing proper; and third, drying. The first operation consists in boiling and scouring the material; this is performed in vats, the scouring being accomplished either by hand or automatically by scouring machines. This operation carries no special danger from fire with it, except where *oily* material is scoured, and then allowed to lie in heaps. When this is the case, we have one of the most favorable circumstances for spontaneous combustion.

The custom of some dyers of adding oil to the stock in the dye-tubs, to soften it, is a bad one. If properly dried, the oil is superfluous; if dried too hot, the presence of the oil in the stock materially increases the hazard of fire, from ignition of the damp, oily stock, subjected to the heat of the drying chest.

The process of dyeing creates no danger from fire; a hazard lies in the chemicals stored for the process. We find here unslaked lime (which, on getting damp, has caused fires); sulphuric acid; piles of logwood in the process of "curing," damp and liable to ignite spontaneously, etc. Although we have never heard of a fire caused by the spontaneous combustion of logwood, yet from what such eminent chemical technologists as Muspratt and Stohmann tell us of the nature of the process of "curing" logwood, it seems quite probable that fires may originate through its agency. Chlorate of potassium is also sometimes stored, concerning the hazards of which I will speak later.

After dyeing, the material is sometimes sized and (whether sized or unsized) dried; and it is here that fires in dye works chiefly occur. The danger of a dry house depends greatly on the material dried; for piece goods, warps or yarns, the danger is not so great as in the case of raw stock, and especially raw cotton. In the hot summer months, yarns, and, sometimes, even raw stocks are dried on "drying flats;" but, as a rule, they are dried in rooms heated by steam, furnaces, or by the natural heat of the boilers below. The steam pipes are arranged to run either along the floor, the wall, or, which I am sorry to say is seldom the case, along the main ceiling. The last arrangement is preferable, as in that case it will be impossible for the material to drop on the pipes. In this method of drying, the only requirements are that steam pipes rest on iron (as live steam pipes will ignite wood) and that the steam pipes are kept clean. The antiquated method of drying by furnaces is very objectionable, and has, in our country, been almost entirely superseded by the much safer process of steam drying. The last method, which is frequently used where drying rooms are situated over the boiler room, is the most economical process; and, when properly constructed, so that no yarn dust or fibres may fall within dangerous proximity of the boilers or boiler fire, has no special hazard connected with it. Special care should in this case be taken to have the boilers well enclosed by brickwork, and where this is not the case, a thick layer of sand should be spread on top of them, thus protecting them against falling particles.

The hazard of a yarn dry house varies with the nature of the yarns dried. It is safer to dry woolen and worsted than shoddy, cotton or jute yarns. Care must be taken to remove from the steam pipes under the floors all the fly and bits of yarn which may accumulate thereon. It is not advisable to have lights in dry rooms. Lights become especially hazardous when shoddy yarns, spun with low grade wool oil, or heavy black petroleum oils, are used. It is a well-known fact that oils of this kind cannot be saponified and washed out before dyeing, and must, therefore, be present in the yarns when the latter are dried. The heat of the dry rooms soon evaporates the lighter products of the petroleum, and in a short time the dry house is filled with very inflammable vapors, which would be readily ignited if brought into contact with an open light.

The custom of filling the dry house with yarn in the evening and turning on the steam in order to do the drying at night, when the rest of the mill is not in operation, is a very bad one. The majority of our dry house fires occur towards morning, and, as a rule, on damp nights, when the moisture of the outside air prevents the escape of the hot air through the ventilators in the roof, and when the person in charge has turned on a full head of steam to overcome the increased moisture of the air in the dry house.

Ventilators in the roof of the yarn dry house which, if closed, open automatically when a dangerous temperature is reached in the dry room, should never be omitted.

In the dyeing of raw stock, especially of cotton, the conditions are changed, and even the best method is dangerous. This stuff will flash and spread in an instant, and before the hands employed have time to save themselves, everything is in flames. The apparatus for drying raw stock usually consists of a box closed at the top by a screen (over which the material is placed), a fan or blower, and the steam pipes for supplying heat. It is apparent that these may be put together and arranged in the following ways: Either the fan and pipes are in the box beneath the screen, or the pipes are outside and the fan under the screen, or the fan is outside and the pipes inside, or both are outside. The first arrangement is the poorest. In this case, the fan would draw the air from outside, force it over the steam pipes and into the stock; if a piece of cotton should fall on the pipes below it might ignite and impart the flame to the stock above. Besides, in all cases in which the fan is below the stock, the shaft and other working parts soon become covered with fuzz; this soaks up the oil with which such machinery must constantly be lubricated, and should at any time the journals, from some cause, as for want of oil, become hot, the greasy waste becomes ignited, and the flames ascend to the stock. Hot journals, on all kinds of machinery, are by no means seldom occurrences; the skillful inspector may frequently have noticed by a test, (not very æsthetic but practical), *i. e.*, spitting on the journals of revolving cards, etc., how the saliva instantly vaporized into a cloud of steam; and the impatient traveler may often have wondered "what are they stopping for," when the simple cause was a hot journal from an unoiled axle.

The second method of drying is better than the first, but is still subject to the latter objection; in this case, the steam pipes are above the stock, and the hot air is sucked through the stock by the fan (blower) beneath. The next is but the reverse of the foregoing, and is seldom employed.

The last is the best; in this case, the steam pipes are over the stock, while the fan sucks the hot air through the stock by a flue, which is connected with the box. A method often advised by some insurance men, but which I believe to be objectionable, is the following: The pipes are outside of the box, and on a lower level than the drying stock, the fan or blower being also outside and lower than the stock. The fan sucks the hot air from the pipes and blows it through a flue into the closed space under the stock. Now let us suppose that a thick layer of moist stock be laid on the screen, and observe the effect. The layer of moist stock will be almost impervious to a current of air, the hot air from the fan will be confined, cannot escape from the enclosed space below the screen, but the fan will continue pumping hot air into the box until very soon a dangerous temperature is reached.

There is also another mode of drying, but which, on account of the slowness of the process, is not much employed; that is, by cold air. The cold air dryers consist of a chest and fan or blower like the foregoing, but instead of using artificially heated air, they force through the stock, air from the room, at the same temperature as the surrounding atmosphere. These dryers are very safe; but, as before stated, on account of the slowness with which they work, are not much in use.

When steam coils are used much depends on the construction of the box enclosing the pipes. This box should be of iron. It is necessary to have an opening to the box to facilitate the cleaning of the steam pipes.

When air is sucked over the steam pipes, and then blown out through the stock, the air-opening in the chest containing the steam pipes, should, in all cases, be provided with a wire screen to prevent particles of stock from being sucked into the chest. Such stock, accumulating on the spaces between the hot pipes, will soon char, and frequently, when the fan is started after a short stoppage, the air blast will ignite this charring stock and carry it into the chest, causing ignition of the fly which will always be found in the chest.

Special care must be taken to provide an escape for hot air after it has passed through the stock, and the idea of providing no escape for the hot air from the enclosed space, in order to keep the heat in to do good and rapid drying, is erroneous. The air confined in the enclosed space, although hot, is so laden with moisture that, instead of helping the drying, it retards it. The hot, moist air must be got rid of to insure rapid drying. Ventilation is absolutely necessary to rapid and safe drying. When ventilation is provided, dry, hot air will be constantly supplied to the stock, and the accumulation of hot air in an enclosed space will be prevented.

Systems so arranged that the fan takes the hot air from the enclosed space above the stock, and forces it over the steam pipes a second time, so that the same air is used over and over again, I consider not as safe as a system where the moist air is allowed to escape. The continued reheating of the air will soon raise its temperature to such a point that it will do the stock more harm than good. Dyed cotton dried in this way is likely to be very harsh to the touch, and very hard to work on the cards. The drying of raw wool is not by any means as dangerous as that of raw cotton. Nor is exhaust steam as hazardous as live steam.

The simplest and safest method of drying raw stock is, without doubt, the frame drying-flat, either on the roof of some low building, or on the ground. Stock dried by this method is uniformly dried. It does not show signs of baking, and works easily and softly on the cards, less oil being necessary, less fly being thrown off, and hence less hazard in the card room. The last is a very important factor of safety in a mill where dyed cotton (black or brown being the most hazardous) is used on woolen machinery. The system of drying by cold air is similar in its effect on the stock.

Where certain kinds of dyed cloth or yarn are dried, special care must be taken to prevent their spontaneous combustion; especially those in which the required shade of color has been produced by chemicals which absorb oxygen from the air, forming new compounds which produce the desired shade. The warmer the material comes from the drying cans, the less heat by slow combustion or oxidation is required for it to reach the ignition point, at which it starts into active combustion; or when it is tightly rolled or densely packed, the heat produced by the chemical action is not conducted away as readily as when it is exposed to the free circulation of the air, and, thus accumulating, soon reaches the ignition temperature of the mass. Fires of this nature have been caused by materials colored with browns made from catechu, cutch, gambier, or terra Japonica; iron buffs, indigo-blue, and cloth prepared with oil for Turkey red; and even, though but seldom, in logwood and iron blacks; and more frequently in blacks made from aniline and its salts. Spontaneous combustion can be prevented by cooling the goods thoroughly as they come from the drying cans and submitting them to the action of the atmosphere on all sides. They should never be piled in quantity or put up in rolls until these precautions have been taken. Sized goods are not as apt to ignite spontaneously as those which are unsized; but such cases do happen and are especially apt to occur where much tallow has been used in the size, since animal fats are prone to ignite damp goods spontaneously. Fires have been caused by supposed well-cooled goods being piled over night. All goods received from drying cans before closing in the evening should be placed in a fireproof room for the night, which, in order to insure frequent inspections, should be one of the watchman's stations, and should be provided with automatic sprinklers and steam jets. When the steam supply pipes are properly hung (free from wood-work) and when proper ventilation is provided, there is no special hazard connected with a steam drying cylinder, either when drying piece goods or warps.

Especial care should be exercised in singeing. Goods should not be rolled or piled in quantity before being well cooled, and examined for glowing particles which may have remained in them.

Cloth, when woven of yarns spun with wool oil containing low test petroleum, gives off dangerous vapors, if subjected to a high temperature on the cylinders. I would, therefore, advise to have no artificial light in inclosed rooms where this operation is carried on.

Tentering machines, both horizontal and upright, extending through one or more floors, when properly put up are not very hazardous. The steam pipes must be frequently cleaned off to remove all fly which will accumulate on them, and when the tentering machine is in an inclosed room, ventilation is as necessary as in every other process of drying.

As before stated, chlorate of potassium is now much used in the preparation of aniline blacks, which are considerably used in print works. The danger of potassium chlorate may best be illustrated by a little experiment.

Before you, on this table, I have a mixture of chlorate of potassium and finely powdered sugar. If I add but a drop of sulphuric acid to it, the same will ignite with almost explosive violence.

[This experiment was performed.]

The reason for this, is, that the sulphuric acid abstracts the elements of water from the sugar, thereby generating sufficient heat to ignite the charred residuum, while the combustion is fed through the oxygen contained in the chlorate of potassium, a substance which parts very readily with the oxygen it holds in chemical combination. The terrible explosions and fires which from time to time occur in candy manufacturies, manufacturing chlorate of potash drops, may now no longer be a mystery to you, as they have been, to many experts, consulted at the times of their occurrence.

PICKING.

After the raw stock has been properly dyed and dryed it must be willowed to remove the dirt; picked to reduce the knotted and tangled fibres, and mixed in proper proportions to facilitate the work on the cards.

The picking of the stock is justly considered the most hazardous operation in a mill.

The danger of the picker is the possible presence of foreign particles, such as stones, nails, etc., in the stock, coming in contact with the rapidly revolving cylinder of steel prongs, causing sparks and fires.

The hazard is proportionate to the inflammability of the stock. The willow, owing to its slow motion, and to the size of the teeth, which are frequently of wood, is not as hazardous. On the contrary, willowing the stock before picking it reduces the hazard materially, since most of the dust and foreign substances will be removed.

The mixing picker is the most hozardous, since the various grades of stock are passed through it at one time, the hazard being further increased by oiling the stock. Saponifying the oil reduces the hazard. This is done by adding either ammonia, potash or borax to the oil. Where the largest percentage of the mixing is cotton, a cotton-spreader is used, which is quite as hazardous, owing to the nature of the stock. Frequently a cotton-opener is used. This machine has caused so many fires that some managers have returned to the slower but safer process of "opening" the cotton by hand, or by a willow, before feeding it to the spreader.

In no case should open lights be permitted in picker rooms. Even inclosed lanterns will be a source of danger from the possible ignition of dust, which may accumulate on the top of the lamps, and which, igniting, may drop into a pile of loose stock. A light set in the wall provided with a heavy brass plate flush with the inside wall, and arranged to be lit from the outside only, is a very safe light for a picker room. Incandescent electric lights when properly installed are excellent for picker house lighting.

Manufacturers frequently use their clean waste as a part of their "mixing." Where soft waste alone is used, no additional hazard is added to the picker room. Should, however, hard waste be used, a hard waste picker becomes necessary; this is one of the most hazardous pickers, equal in danger to the rag picker, which it resembles in construction. Careful managers, cognizant of this fact, do not pick their own hard waste, but send it out to be picked at shoddy mills.*

When a picker strikes fire, the burning stock will naturally be blown into the loose stock collected in the picker-box, hence the construction of this box is a very important point. In mills in the vicinity of Philadelphia, this box varies with the nature of the stock used. When pure wool only is used, the picker-box is often dispensed with. Where rags are picked, it is generally fire-proof. A substantial picker-box is preferable with any kind of stock. The best construction for the purpose is undoubtedly a brick chest with brick-arched ceiling with an iron-lined door at one side and an iron-lined slide to close the opening in front of the picker in case of an accident. An opening beside the door, which should be always closed when not used, is necessary for the passage of the air-blast. This opening can be readily made "fire-tight" by covering it with good strong wire-matting of close mesh. In place of this opening I would suggest a brick flue passing out of the roof of the picker-house, which can be protected from the rain, and will act as a chimney in case of a fire, being a natural outlet for smoke and flames without endangering the remainder of the picker-room. The only loss then will be the burning of the stock in the picker-box, at the time the picker strikes fire.

The flue from the picker to the dust-box, which should, in all cases be outside of the building (in some instances the dust-box is in a corner of the basement of the main mill) is best made of sheet-iron.

An undetected fire smoldering in the dust-box would soon find its way through a wooden spout into the picker-room after the picker is stopped. A light iron plate at the end of the metal spout so hung that it would be kept open by the air-blast when the picker is in operation and closed by its own weight when the picker is stopped, would be an efficient cut-off for a fire starting in the dust-box

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* I am indebted to Mr. C. A. Hexamer for much valuable information in regard to pickers and picker-house construction, and have made copious use of his notes on the subject.—C. J. H.

One of the most objectionable features in the usual construction of the picker-house is the size of the edifice. In the majority of mills the picker-room is also used as a mixing-room. A trifling fire, when fed by a day's mixing and a week's stock in bales, will soon cause a heavy loss. The picker-room should be as small as possible, so that the temptation to make it a stock-room will be overcome. The mixing-room can be located in a separate room, separated from the picker-room by a brick wall and a good iron-lined door. Where the yard space is limited, the mixing-room may be built above the picker-room, An opening may be made in the fire-proof ceiling of the picker-room· through which the stock can be lowered when ready for the picker. This opening in the ceiling should be provided with a fire-proof cover so arranged that it will always be closed when not in use. I would advise to have the stairway leading to the mixing-room in the second story built on the outside, so that there be no other opening in the ceiling, except the one closed by the fire-proof trap-door. If the brick flue from the picker-box is used, it must necessarily extend through the mixing room and out through the roof of the building. Steam pipes for heating the mixing-room are only safe when suspended from the ceiling. Many fires have occurred from spontaneous combustion of oiled stock piled against steam-pipes The danger from this source varies with the nature of the oil used on the stock.

When "phosphor-bronze" came into use some years ago, Mr. Edward Atkinson suggested the substitution of this alloy for iron whippers in the beater, as these would be less apt to produce sparks on coming in contact with foreign matter. He had an experimental picker manufactured, on one-half of the beater of which, ordinary whippers of Norway iron were used, and on the other half, those made of phosphor-bronze. Mr. Woodbury describes the results of experiments made with it as follows: "When the picker was in operation a number of pieces of iron were fed in, and a shower of sparks was emitted from the iron, but not from the 'phosphor-bronze' beaters; pieces of hard steel were substituted for the iron fed in, but with the same result. Phosphor-bronze whippers have been used in the same beater with Norway iron whippers for eighteen months; at the end of that time, the iron whippers had worn into the steel rods to which they were hinged, while there was no perceptible wear between the steel rod and the phosphor-bronze whippers. The working edges of the phosphor-bronze whippers were sharper than those of iron. The results of extended investigations in the merits of this alloy show that it is superior to iron in safety, durability and efficiency."

CARDING.

The stock having been picked is now ready for the cards. The object in carding is the cleaning of the stock of dirt and foreign matter which may have remained after the picking, and to "card out" the short fibre of the stock, at the same time placing the various strands in parallel layers to facilitate the subsequent spinning. Cards are generally arranged in sets of three, and occasionally, of two and four.

A card consists of a large cylinder from three to four feet in diameter covered with card cloth (leather or rubber strips perforated by numerous steel wires of equal length), and of a number of smaller cylinders from six to eight inches in diameter. The smaller cylinders revolve in opposite directions to the large one; that known as the "fancy" revolving very rapidly. Where cotton or shoddy is used, the fancy should in all cases be provided with a metal cover, so that the short fibre carded out may be prevented as far as possible from flying about. The rapid revolution of the fancy makes it necessary to keep the journals of this cylinder well oiled. Carelessness in this respect has caused many card-room fires.

The hazard of the card-room consists chiefly in the accumulation of the particles of stock carded out, which, on account of their extreme lightness, fill the air of the room, and in settling, cover everything with a very inflammable substance usually known as "fly." As a general rule, the poorer the grade of stock, the greater the amount of fly created, hence the greater the hazard of the card-room. Wool alone, when run over the cards, does not create much fly. When cotton or shoddy is mixed with it, the amount of fly is greater; when cotton alone, especially dyed cotton, is run over woolen cards, the accumulation of fly, and hence the danger from fire, is greatest.

No doubt many of you have heard of the terrible explosions and fires which from time to time occur in flour mills. The reason for this, is, that when any organic substance, such as flour, is finely divided and mixed with air, it will, on coming in contact with a flame, be almost instantaneously ignited; the products of combustion being gases of many hundred times the volume formerly occupied by the dust, these, on expanding, create explosions.

If we enter a carding-room, in which cotton is worked over open woolen cards, we find a condition of things almost analogous to that in a flour mill. The entire air of the room is filled with a finely divided organic substance which, under certain circumstances is even more explosive and liable to ignite than finely divided flour. The only reason that we have not the severe explosions, for we frequently have the almost instantaneous fires, that we have in flour mills, is that the card-rooms are, as a rule, large, and the gases caused by the almost instantaneous ignition find means of exit without causing explosions —while in flour mills we have numerous enclosed spaces, such as smutters, mill boxes, elevator-boots, etc.

A substance becomes the more inflammable, the greater its affinity for oxygen; thus the combustibility of a fibre increases directly with the avidity it has for the oxygen of the air. If, therefore, in the processes of dyeing, the property of uniting readily with oxygen has been imparted to the fibre, the finely divided fibres, commonly called "fly," are more apt to ignite. It is for this reason that fibres dyed with certain chemicals which absorb oxygen are much more hazardous than the ordinary raw stock. Cotton, the purest form of cellulose in nature, after treatment with chemicals required for the production of some colors, undergoes a change of state, in which it resembles guncotton.

You will, by this time, have perceived the reason why the so-called mixed mills are so much more hazardous than the ordinary pure stock mills; the reason being that in the former, cotton, and, frequently, dyed cotton, is worked over open woolen cards, creating a vast amount of fine, extremely combustible and explosive cotton fly.

In order to test the explosiveness of different dusts, I have constructed an explosion apparatus.

The questions to be determined for every kind of dust are at what degree of humidity it will cease to explode, how finely divided each kind of dust must be in order to explode; and the determination of the temperature at the time of explosion. [A large drawing of the apparatus was shown.]

The apparatus consists of an ordinary kitchen boiler (such as is used for heating water), with its top taken off. This top may be closed by a ring over which tissue paper has been pasted, and the ring is tightly screwed on as shown in the drawing. In the interior you will perceive two hooks, one being for the reception of a thermometer by which the temperature of the atmosphere in the interior may be obtained before exploding the dust, and the other for a hygrometer, by which the humidity of the contained air is determined. In the bottom of the apparatus a gas pipe is inserted, the jet being lighted (in order to secure greater safety) by electricity from a distance. On the upper end a funnel with a blower is attached, by means of which the finely-divided dust may be blown in. In order that I may not be dependent on the surrounding atmosphere for the temperature and the humidity of the contained air, a small boiler is connected with the apparatus, by means of which steam may be blown into the interior, and thereby any degree of humidity produced that is desired; while the temperature may be regulated by the gas jet burning in the bottom.

The manner of using the apparatus is as follows: After the temperature and humidity of the enclosed air have been determined, the thermometer and hygrometer are removed, the cap with the tissue paper cover is tightly screwed on, and the dust blown in. When a short time has been allowed the dust to mingle with the contained air, the gas jet is lighted by means of electricity, and the explosion occurs.

I am now engaged in making numerous experiments with various kinds of organic dusts, which are produced in different technical occupations; and will publish the results of my experiments, when they are completed.

SPINNING.

From the cards, the stock is taken to the spinning frames, and this department is one of the most prolific sources of fires caused by friction, especially in the mule heads, which should be kept thoroughly clean and lubricated. The ends of the carriages next to the head should be well closed, with an opening just large enough for the drum cords. When fires originate in mule heads, the flame is transmitted throughout the machine with almost instantaneous velocity, unless the carriage is kept very clean and clear of oily waste.

OILS.

Statistics of fires among New England mills have shown that 37 per cent. of fire losses are caused by spontaneous combustion, and hot journals from friction caused by bad oils. A good lubricating oil should be neither acid nor strongly alkaline; nor should it, through variations in temperature, become acid or alkaline. Most vegetable and animal oils, when they are exposed to high temperatures, such as that of superheated steam, are decomposed, and acids are set free; as they are composed of stearic, oleic and palmitic acids combined with glycerine. These free acids corrode the surface of the metals, making them rough, and forming compounds which are the very opposite of lubricants. Their use, therefore, for journal-boxes, in hot weather, or where they become heated, is to be deprecated, for at high temperatures they combine with the oxygen of the air and decomposition results.

A mineral oil never becomes acid from decomposition, and will not corrode the metals to which it is applied. When these oils are mixed with glycerine, they form a very good lubricant. The great danger in buying mineral oils is that large quantities are annually put into the market far below the necessary flash test. These oils should be prepared by fractional distilation at a temperature not below 500° F. When mineral lubricants with a low flash test are used, they are exceedingly dangerous, as, on becoming heated in the journal, the volatile parts go off as vapors, making it dangerous to examine a journal or any other part with an open light. In order that a mineral oil should be a good lubricant, it should not flash under 300° F.; should not give off more than 5 per cent. of volatile matter at 140° F. in twelve hours; should be free from grit; and should contain no free acids or alkalies.

To determine the flash test accurately, an instrument too complicated for the use of the ordinary manufacturer is required; but he may, for his purpose, approximately determine the same by pouring the oil in a flat dish, which is placed on a plate containing dry sand, to which heat is applied (so as not to apply the heat to the oil directly), thus causing a gradual heating of the oil. A thermometer is then inserted some distance from the bottom of the dish, and the rise of the temperature noted. A lighted taper is then moved over the surface of the oil, care being taken not to touch it. If the vapors given off by the oil flash below 300° F., the oil is to be condemned as unfit to be used as a lubricant.

To determine the amount of volatile matter in an oil, the sample must be carefully weighed on a fine balance, and then exposed to a temperature of 140° F. for ten or twelve hours; then, after cooling, reweighed. The loss will represent the amount of volatile matter given off in that time. If the loss be more than five per cent. the oil should not be used.

In order to determine the amount of solid foreign matter (such as grit) in oil, a sample very near the bottom of the barrel (as the greater gravity of the solid material will cause it to settle on the bottom) should be taken and placed between two clean glass plates and then rapidly rubbed together, when the grit will at once be detected.

Acids or alkalies in oil may readily be detected by means of litmus paper. If blue litmus paper is dipped into an oil containing acids, it will be colored red, while red litmus paper is turned blue when dipped into an oil containing alkalies. Any oil giving an acid or strong alkaline reaction should be condemned.

Mineral oils sometimes give an acid reaction, not from any decomposition of the compound, but from the sulphuric acid used in the processes of manufacturing it, which has been incompletely neutralized with caustic soda. If the amount of soda has been too small, an excess of acid remains; while in the presence of an excess of soda, a residual amount of soda will remain, which also has a bad influence on the metal bearings.

A test for sulphuric acid can readily be made by mixing a sample of the oil with water, and after shaking it well, allowing it to stand until the oil separates from the water, which is then poured off. On account of its hydroscopic properties the sulphuric acid will have united with the water. If now a solution of a barium compound be added to the water, a white precipitate of sulphate of barium will at once be caused, if sulphuric acid be present in the oil. In order to make the test sure, as there are other acids which throw down a white precipitate, the precipitate must be treated with strong nitric or hydrochloric acid, and if it remains unchanged, sulphuric acid is contained in the oil.

If the litmus paper shows the presence of alkalies, these may be tested by treating the oil with water, as before described, then evaporating the solution to dryness, and placing the residue in the colorless flame of a Bunsen burner. Sodium will give an intensely yellow flame, if potassium be present a beautiful violet flame will be produced.

Adulterations of animal oil or mineral oil may be detected by adding concentrated sulphuric acid, when the animal oil will be charred, forming black rings in the sample. Vegetable or animal oils can also be detected by adding an alkali to the sample, thus causing these to saponify; as mineral oils have not the property of saponification. Oils are frequently adulterated with cotton-seed oil, which is prone to ignite waste spontaneously.

SPONTANEOUS COMBUSTION.

Numerous fires are caused by what is commonly known as spontaneous combustion. Spontaneous combustion of oily rags or waste is caused by a rapid absorption of oxygen from the air, oils which have a great avidity for oxygen being the chief causes. By a number of experiments, it has been shown that when vegetable or animal oils contain one-third, or over, mineral oil, they will not ignite waste impregnated with them, spontaneously.

I have not time enough this evening to go into a lengthy discussion of spontaneous combustion and its causes, but must refer you to my work on "Spontaneous Combustion," which will shortly appear, in which this branch of the subject is treated in detail. I will merely give you the experiments of Dr. James Young, which are before you.

TEMPERATURE OF CHAMBER FROM 130° F. TO 170° F.

Boiled linseed	oil	on cotton	ignited in	1¼	hours.
Raw	“	“	“	4	“
Lard	“	“	“	4	“
Colza	“	“	“	6	“
Olive	“	“	“	5	“

Seal oil and mineral oil, equal parts, on cotton, would not ignite.

TEMPERATURE OF CHAMBER FROM 180° F. TO 200° F.

Colza oil on wool	ignited in	6	hours.
Olive oil on cotton	“	2	“
Olive oil on wool	“	7	“
Seal oil on wool	“	3	“
Whale oil on jute	“	9	“
Whale oil on cotton	“	3	“
Cotton-seed oil on wool	“	5½	“

The following were not ignited by twenty-four hours' exposure in the hot-air chamber:

Olive oil and mineral oil, equal parts, on cotton.
Colza oil and 20 per cent. mineral oil, on wool.
Seal and mineral oil, equal parts, on wool.
Whale and mineral oil, equal parts, on jute.
Cotton-seed oil and 20 per cent. mineral oil, on wool.

The following table exhibits the results of the experiments of J. J. Coleman:

	Entered into combustion after	At a temperature of
Cotton waste saturated with whale oil	3 hours.	165° C.
Cotton waste saturated with olive oil	4 "	177° C.
Olive oil and 20 per cent. mineral oil	8 "	177° C.
Mineral and olive oil, equal parts, no change after lapse of 26 hours, after 12 hours, temperature 95° C		
Wool waste and seal oil	3 "	194° C.
Wool waste and whale oil	3 "	188° C.
Wool waste and cotton-seed oil	5 "	178° C.
Wool waste and olive oil	7 "	177° C.
Wool waste and refined rape oil	6 "	177° C.
Wool waste and crude rape oil	8 "	163° C.
Wool waste and cotton-seed oil with 20 per cent. mineral oil; seal and mineral oil, equal parts; olive and mineral oils, equal parts, unaltered after lapse of 26 hours.		
Jute waste with whale oil	8 "	180° C.
Jute waste with whale oil and mineral oil, equal parts, unchanged after 26 hours.		

I am at present engaged with a number of experiments on spontaneous combustion with very carefully constructed apparatus, which, I hope will prove more accurate than those formerly made with cruder apparatus.

[A large drawing of the apparatus was shown.]

The figure before you illustrates the device. Inside of the upper half of a strong metallic box, divided in two by means of a metallic partition, is placed a wire cage containing the material saturated with the oil to be experimented with. The wire box is surrounded by an air space on all sides, being, for this purpose, placed on legs, so as not to be in direct contact with the metallic surface of the partition. The lower half of the subdivided box is connected with a small boiler in which steam is generated (by means of a Bunsen burner), and the steam entering the lower half of the box produces an equalized temperature in the upper division, while the material to be experimented with, is surrounded and submitted to the action of the air on all sides. A thermometer is inserted in the upper partition, by means of which the exact temperature in it may be noted. In order to increase the temperature to any desired degree, the steam which passes through a strong pipe from the boiler to the lower half of the box, may, in its passage be heated to any desired temperature by applying a Bunsen burner to the pipe. In order that the rise of temperature in the mass before ignition may be noted, and also the exact time when ignition has set in, a number of thermostats, set for various temperatures, are placed in the mass experimented with. These, as well as a conductor with a fusible solder link in it, form electric circuits, and are connected with electric clocks. As soon as the temperature corresponding to each thermostat is reached, the contact is broken, the clock stopped, and the interval between starting the experiment and this time can be noted, while the time of ignition of the mass is indicated by the stopping of the clock placed in the circuit containing the fusible solder joint. That the amount of humidity (which plays an important role in the spontaneous ignition of waste) may be varied, a small steam boiler, like the one described in the explosion apparatus, is connected with the upper chamber, and any desired quantity of steam may be blown into the same, and the humidity of the contained air altered at will.

I have spoken of the importance of the microscope in relation to testing textile processes, and will now show you a series of microscopic slides thrown on the screen, greatly enlarged. Fine fibres, which ordinarily are hardly visible to the naked eye, will be seen projected on the screen four, and on the rear wall, eighteen inches in diameter. This is accomplished by means of Mr. Holman's excellent lantern, a one-tenth immersion lens being used (the object and the lens being both immersed in glycerine); the entire light of a large electric arc lamp being concentrated through a small aperture not much larger than the head of a pin, and projected on the screen.

The following fibres were then shown on the screen:

1. Cotton fibre fresh from bale.
2. Cotton from bale dyed with aniline black.
3. White carded on flat cards.
4. Gray 1 and 2 mixed, carded on flat cards.
5. Gray 1 and 2 mixed, carded on worker and stripper cards.
6. White (3) spun in three thread loosely.
7. No. 3 dyed light-blue spun in 3 loosely.
8. No. 3 dyed deep-blue spun in 3 loosely.
9. No. 3 badly dyed red, spun in 3 loosely.
10. Sea Island spun white in six cord, tight.
11. Sea Island deep-blue in six cord, tight.

12. Sea Island badly dyed red in six cord, tight.
13. Flax (raw fibre).
14. Jute (fibre).
15. Sheep's wool donskoi. (The scale-like structure was shown highly magnified with great clearness.)
16. Silk fibre reeled and dyed.
17. Fabric (silk-poplin) wool, silk and linen.
18. Fabric (all-silk).
19. Wool waste.
20. Extract of wool.
21. Silk noils.

ELEMENTS OF SOLAR ROTATION.—Spörer has tested his own observations by means of the result which was pointed out by Faye, that the proper movement of the sun spots in latitude can be represented by a sinusoid. The direction of the spots in the equatorial regions mainly toward the equator, while the movement toward the poles predominates in high latitudes, might be explained by supposing that the spots in the former case were on the descending branch, and in the latter on the ascending branch of the curve. This would require, however, that the spots should be hidden, for some unknown reason, behind the sun's disc when they were on the other branches of the curve. He gives various other tests, under various hypotheses, each of which involves an indeterminate condition. There was, however, one spot which remained visible during four consecutive rotations of the sun, and for which he was able completely to observe the sinusoid of the variations in latitude in all the periods. He was able to determine the sinusoid, independently of the node and of the declination, by means of the intersection of the curves with the parallels of latitude which he obtained for the first and second, as well as for the second and third periods. The sinusoid thus deduced for the three periods also satisfied the observations of the fourth.—*Comptes Rendus*, May 19, 1884.

[Faye's remarks upon the above communication, as well as Lamey's explanation of the conservation of solar energy (*C. R.*, May 26, 1884), corroborate Chase's theory that the fundamental velocity of solar rotation, as well as of rotation at the centre of all other stellar systems, is always dependent upon the velocity of æthereal undulation.] C.

OPTICAL EXPERIMENT.—Take a piece of paper or cardboard, pierce a very small hole with the point of a pin, and hold it with the left hand at about 18 inches from one of the eyes. Stand so as to have the hole illuminated by daylight or lamplight, then introduce with the right hand the head of a pin between your eye and the hole. The shadow will be thrown upon the retina in such a way that the pin will appear to be reversed.—*Les Mondes*, Jan. 12, 1884. C.

ECONOMY IN THE USE OF HIGH PRESSURE STEAM.*

By William Barnet Le Van.

The importance of the use of *high pressure steam* cannot be too constantly urged upon engineers and manufacturers, and that the employment of low pressure steam in engines is extremely wasteful; yet, clear as this is or should be to all intelligent engineers and steam users, they do not recognize the truth. One may often hear an engineer boasting, "I have got an extremely good engine; its 'boss,' she will drive the whole load with forty pounds of steam," never reflecting that, when he is using steam at only forty pounds above atmospheric pressure, in a non-condensing (high pressure) engine, one-third of the whole of the fuel is consumed in getting the steam up to the atmospheric pressure; while, if he were to use the steam at one hundred and twenty-five pounds to the square inch, only one-ninth of the fuel would be so wasted.

When steam is used in non-condensing engines, at low pressure, the loss is great, owing to the pressure of the atmosphere (14·7 pounds), being a greater percentage if a low pressure is used than a high pressure.

The loss for different piston pressures is as follows:

Atmospheric pressure.	Steam pressure in boiler.	Total pressure on engine piston.	Percentage of loss.
15	5	20	$\frac{3}{4}$ or 75· per cent.
15	10	25	$\frac{3}{5}$ or 60· "
15	15	30	$\frac{1}{2}$ or 50· "
15	20	35	$\frac{3}{7}$ or 44·4 "
15	25	40	$\frac{3}{8}$ or 37·5 "
15	30	45	$\frac{3}{9}$ or 33·3 "
15	35	50	$\frac{3}{10}$ or 30· "
15	45	60	$\frac{1}{4}$ or 25· "
15	60	75	$\frac{1}{5}$ or 20· "
15	75	90	$\frac{1}{6}$ or 16·6 "
15	90	105	$\frac{1}{7}$ or 14·2 "
15	100	115	$\frac{1}{8}$ or 12·5 "
15	125	140	$\frac{1}{9}$ or 11·1 "

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* Read at the Stated Meeting of the Franklin Institute, February 18, 1885.

This has reference only to the pressure on the piston in the cylinder of the engine, and does not refer to the boiler pressure, as indicated by the steam gauge.

It has been proven, both in practice and theory, that the *greater* the *difference* between the *steam pressure on the piston* and the *resisting forces* of the *condenser, or atmosphere*, the *higher* will be the mechanical efficacy of the steam; and hence the necessity of employing *high pressure* steam, in order to obtain the fullest effect of *expansion.*

It is a well-known fact that the secret of economy in running steam engines lies in the adoption of the highest practicable pressure of steam, thorough jacketing about the cylinders, steam pipes and steam chests, the earliest cut-off at which the engine will do its work, and as perfect condensation of steam as possible after the steam has done that work.

No engine can run economically at a high grade of expansion, except it be fitted with a condenser; for the greatest economy of expansive working lies in expanding below the pressure of the atmosphere. The highest attainable economy would be in expaning down to a perfect vacuum.

In the boiler, the test of economy is the quantity of water evaporated into dry steam for each pound of coal burned. If this quantity be above eight pounds, the boiler is economical, and *ten pounds* is the maximum realized in the best boilers. Apart from the evaporative power of the boiler, its cost, durability and convenience for repairs are important considerations, and demand due attention.

In order that the comparative values of high-pressure steam and low-pressure steam may be made quite clear, I exhibit on the screen a theoretical diagram, in heavy black lines, which is intended to show the ultimate practical amount of work to be obtained from a given quantity of water converted into steam at different pressures, and it is based on the fact that in any two boilers, steaming at different pressures, the same amount of fuel will practically evaporate the same weight of water. The steam is expanded down to seven pounds above zero, ($2\frac{7}{10}$) two and seven-tenths pounds to be deducted for back pressure.

The figures on the left give the pressure in pounds per square inch, the lower figures represent inches of stroke.

The explanation is as follows: When using steam at atmospheric pressure, and expanding it down to seven pounds above zero, the cut-off to effect this will be 0·5, or five-tenths of the stroke; the steam will be also expanded 0·5, or half of the stroke; the mean pressure will be 11·96 pounds, and the mean effective pressure 9·26 pounds, and at any other pressure as per following table:

Pressure in pounds per square inch.	Steam cut-off at hundredth of the stroke.	Rate of expansion.	Mean pressure in pounds per square inch.	Mean effective pressure per square inch.
Atmospheric	0·50	0·50	11·96	9·26
10	0·29	0·71	15·96	13·26
20	0·20	0·80	18·38	15·68
30	0·16	0·84	20·17	17·47
40	0·13	0·87	21·61	18·91
50	0·11	0·89	22·70	20·00
60	0·095	0·905	23·70	21·00
70	0·085	0·915	24·50	21·80
80	0·077	0·923	25·40	22·70
90	0·070	0·93	26·10	23·40
100	0·065	0·935	26·70	24·00
110	0·057	0·943	27·20	24·50
120	0·050	0·95	27·70	25·00
130	0·047	0·953	28·60	25·90
140	0·045	0·955	29·15	26·45
150	0·0425	0·9575	29·70	27·00
160	0·040	0·96	30·20	27·50
170	0·0375	0·9625	30·80	28·10
180	0·037	0·963	31·20	28·50
190	0·035	0·965	31·70	29·00
200	0·034	0·966	31·90	29·20

The last column gives the comparative horse-power; for example, if an engine, running with a steam pressure of fifty pounds per square inch, expanding down to its lowest practical limit, namely, seven pounds above zero, will develop twenty horse-power, the same engine, running with steam at one hundred and twenty pounds, and expanding down to seven pounds above zero, would develop twenty-five horse-power with the same consumption of fuel; or, if the horse-power remain the same, the consumption of fuel will be reduced in the ratio of 20 to 25, or *twenty per cent.* in effect.

This is well illustrated in our best locomotive practice where high pressures are used. Take the case of Locomotive No. 10, Class "K," Pennsylvania Railroad; this locomotive develops on an average 700 horse-power for the two hours' run between Philadelphia and Jersey City with an average consumption of 5,775 pounds of coal, or 4·12 pounds per hour per horse-power.

[The speaker here exhibited on the screen, with the aid of the lantern, a *fac simile* of a diagram, showing the action of steam in an advanced type of automatic condensing engine using high pressure steam, developing about *ninety per cent.* of the theoretical diagram.]

IMPROVED HORIZONTAL FLUE BOILER FOR HIGH PRESSURE STEAM.

It therefore, appears, that by the use of steam at high pressures, a steam engine will perform the same amount of work with less steam and fuel.

All engineers agree that the disturbance in the boiler will be much less at a high than at a low pressure, and the escaping steam will therefore carry more water along with it at low pressure. For this reason the use of high steam pressures is desirable.

These boilers present special and exceptional advantages for producing high pressure steam, in the following particulars, the importance of all of which will be obvious to the user, viz., strength and simplicity, freedom from foaming, quick steaming capacity, making dry steam, large releasing surface and steam room, rapid circulation, nearly perfect combustion, safety and economy.

CONSTRUCTION.

The shell is made telescopic and is formed of three single plates, of best homogeneous steel, three-eight ($\frac{3}{8}$) inch thick, 53¼, 54 and 54¾ inches internal diameter, and sixteen (16) feet long. The transverse joints are single riveted, two and one-half (2½) inches pitch. Longitudinal seams, double-riveted butt joints with inside and outside covering strips, with pitch of rivets three and one-half (3½) inches. All the longitudinal joints are placed above the water line. Heads half (½) inch thick steel, well stayed with tee iron and braced to centre shell plate, thus releasing transverse joints from strain. The shell contains thirty-two (32) flues four (4) inches external diameter, well expanded into and beaded over end plates, and so arranged that there is a clear space vertically of three (3) inches between them in the centre of the boiler, and three (3) inches space between shell and flues, to allow a free circulation of the water.

The steam drum is twenty-four (24) inches diameter, eight (8) feet long, five-sixteenth ($\frac{5}{16}$) inch thick, and connected to main shell by one twelve (12) inch neck, and so arranged that it is placed horizontal, while the main shell "rakes" six (6) inches in sixteen (16) feet. All the rivet holes are punched three thirty-seconds ($\frac{3}{32}$) inch less in diameter than the rivet, and when all the plates are brought well together in place by temporary bolts, the holes are reamed fair to receive the rivets, and countersunk slightly so as to form a fillet to rivet heads, the countersinking being done by a steel pin so that there is no reduction in value of the plates as would be the case if cut away by a reamer.

STRENGTH OF MATERIAL.

All the shell plates exceed 58,000 pounds per square inch tensile strength and have an elongation of at least twenty-eight per cent.

A safe working pressure of one hundred and fifty pounds per square inch above the atmosphere is allowed under ordinance of the city of Philadelphia as per formula of Boiler Commission, to wit:

Formula A.

Percentage of the strength of the sheet as compared to the strength of the solid part of the same sheet,

$$\% = \frac{s-d}{s} = \frac{3{\cdot}5 - 0{\cdot}81}{3{\cdot}5} = 0{\cdot}75 \text{ per cent. of seam.}$$

Formula B.

Percentage of the strength of the rivet in the seam as compared to the strength of the solid part of the plate or sheet,

$$\% = \frac{an}{st} = \frac{0{\cdot}5184 \times 2}{3{\cdot}5 \times 0{\cdot}375} = 0{\cdot}77 \text{ per cent of rivet.}$$

Formula C.

Pressure per square inch at which the safety-valve may be set,

$$p = \frac{Tt\,\%}{rf} = \frac{58000 \times 0.375 \times 0{\cdot}75}{27 \times 4} = 154 \text{ pounds per sq. inch.}$$

s = Space or pitch of rivets in inches.
d = Diameter of rivets in inches.
t = Thickness of the plate in inches.
a = Area of rivet holes in square inches.
n = Number of double rows of rivets in the seam.

f = Factor of safety. In this case four is allowed.

$\%$ = Lowest percentage of plate or rivet per formula A or B.

p = Pounds per square inch above the atmosphere, the safe working pressure.

T = Tensile strength of the plate or value in pounds per square inch of section of plate or sheet.

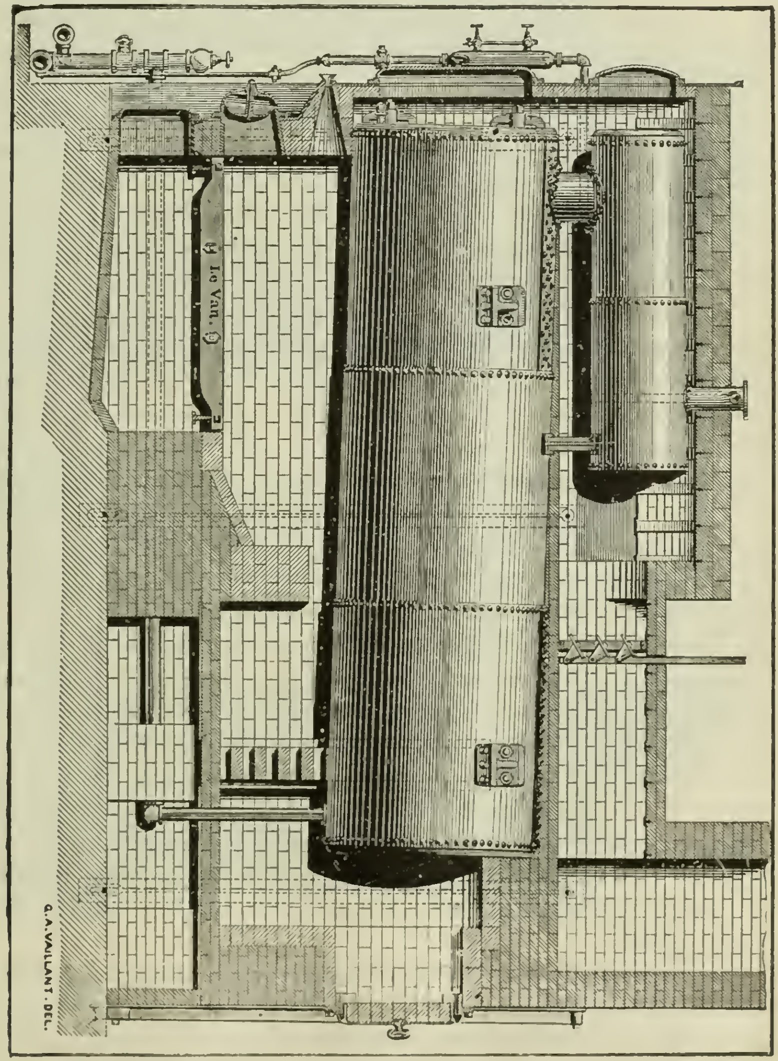

Fig. 1.—Vertical Section of Boiler.

BRICK SETTINGS.

The plan of brick settings shows a large *economy of fuel,* with increased capacity of *steam power.* The arrangement of furnace is such that the heat of the fire is distributed over the whole lower part of the shell. This latter is the result of the arrangement of the system of combustion employed.

The brick work is so arranged as to insure that all the heat evolved by the fuel, and passed over the wetted surface, will be absorbed by the water in the boiler.

It is well known that perfect combustion can only be obtained by supplying sufficient air under the grates and in the combustion chamber, so that the oxygen may combine with all the carbon to form carbonic acid gas before reaching the flues. The production of smoke is an evidence of imperfect combustion, since smoke contains, and owes its existence to, unburnt carbon.

In this boiler furnace provision is made for complete combustion of the fuel before it reaches the flues. The boiler is set from thirty to thirty-six inches above the fire grates, which allows ample room for the air and gases to mix and combine before entering the flues (as can be seen through the observation hole, covered with mica, provided for that purpose). The proper supply of air above the fire grate is under control of the fireman; it is introduced through the fire door, which is constructed hollow, with inside lining perforated with a large number of small holes, and a register on the outside of the door that can be regulated to admit the exact quantity required.

The evil influence of leaving too little room *between the grate and the boiler* may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a gas burner, a little above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered *into the middle of the flame* this will immediately lose its brightness, becoming dull and smoky, covering the bottom of the capsule with soot, and owing to the imperfect combustion, although the water is now surrounded by flame, its ebullition will cease.

It is well established, that below a certain temperature, fuel gases will not burn, and therefore to insure the consumption of all the fuel gases in this boiler furnace before they enter the flues, a division wall or septum separates the fire grate and combustion chamber from the back end of the boiler where the gases enter the flues. This wall, extends up to and completely around the boiler, thus preventing any of the fuel gases from escaping except through the perforations in the wall.

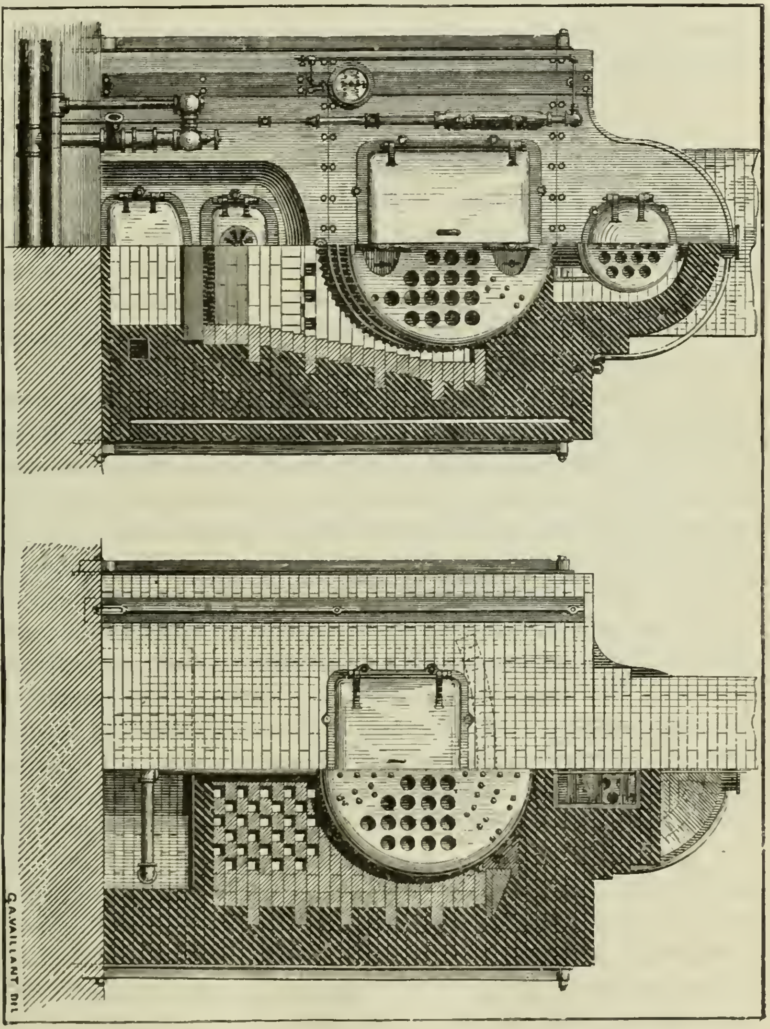

Fig. 2.—Half section of front and through fire-box.

Half section of back and rear combustion chamber.

The fuel gases are thus compelled to come in contact with the highly heated fire brick forming the division wall and form flame which cannot exist below a temperature of eight hundred degrees.

The combustion chamber over the fire grate is continued up to the water line, having a space between the boiler and combustion chamber walls of four inches; thereby allowing the products of combustion to impinge on all the *wetted* surface before entering the flues at its highest temperature, thus securing absorption at the greatest heat, while the balance is passed through the flues and around the steam drum into the chimney at a temperature which renders the use of a separate *economizer unnecessary.*

Above the water line a hot-air jacket space is formed, which becomes filled with the dead gases at a moderate heat and without oxidizing properties due to the sluggish circulation caused by the back end of the boiler being closed in by the division wall, and the front end closed from the water line upwards to the flue formed on the top of the boiler. The effect of this plan upon economy is to dry out any entrained water in the steam of boiler proper, and when it passes into the steam drum to cause a slight degree of superheating.

The advantage of this mode of setting as to durability, must be evident as this is promoted by a temperature maintained as nearly equal as possible on all parts of the boiler shell. The most destructive element to the life of a boiler is by no means the heat, nor is it pressure alone; but it is the tremendous unequal strain when the boiler is warped by the unequal application of heat. A boiler should be kept hot, and kept equally hot all over.

The products of combustion after passing through the flues in the shell of the boiler are conducted under and over the steam drum by forming a flue around the latter with brickwork. The temperature of the steam inside a boiler carrying 100 pounds pressure per square inch above the atmosphere, is about 338 degrees; obviously any reduction of the gases below that temperature would actually *cool* the boiler, while those gases would be still *hot* in the ordinary sense, but would act as a wet blanket on the steam space. But experience with this setting showed that with a chimney of six square feet of area and 44 feet high and burning *pea* coal, the temperature *never* fell below 350 degrees, and the average for over a continuous run of two months was 400 degrees, and an analysis of the gases after passing the steam drum, showed the boiler setting to be correctly proportioned.

SUPERHEATED STEAM.

For some time past engineers have abandoned superheating, although its value is well understood, but this has been from the want of proper packing and lubricants. In the present advanced state of the arts the above objection to its use can now be overcome.

The advantages to be gained in the use of superheated steam cannot be over-estimated. The use of wet steam augments cylinder condensation, whereas by the use of superheated steam cylinder condensation will be reduced to a minimum, from the fact that the latter conducts heat very slowly.

PRIMING.

The worst defect a boiler can have is a disposition to prime; in other words to send water as well as steam to the engine. Whether a boiler primes much or little, the defect is serious. Priming is in conventional terms nothing more than a boiling over. The steam as it is generated, instead of escaping freely from the water, is entangled with it, and carries over in its grasp a certain portion of the fluid.

The Le Van improved boiler overcomes priming by having a steam space, the latter being enveloped in the hot gases at a temperature exceeding that of the steam. The large steam space gives the water time to separate from the steam, also preventing sudden changes in the pressure above its surface. Again, a large water surface acts beneficially by providing an extensive area from which the steam can disengage itself quickly without carrying up much water with it. Furthermore, this boiler like a well-managed household, has a place for everything and everything is in its place, and has numerous other advantages, as follows:

First. It has an ample combustion chamber directly over the fire grate.

Second. It is so arranged that it has a separate supply of fresh air above the fire.

Third. A separate steam space, so that the water cannot encroach upon the steam space, nor steam on the water space.

Fourth. A large water space and the flues so spaced as to ensure of a vigorous circulation.

Fifth. The boiler rakes toward the large end thus insuring that all sediment will gravitate to the lowest point to which the blow-off pipe is attached, and from which it is easily removed by blowing off.

Sixth. The rake or incline of the boiler gives a greater amount of impinging surface for the hot gases to act on.

Seventh. The angle of the back head also gives additional impinging surface.

Eighth. The front head on account of its angular position admits of an earlier and easier release of the gases from the flues.

FITTINGS.

The fittings comprise modern and most approved appliances for safe and economical operation, and include cast iron front, ash-pit, fire and flue doors and frames, with registers to prevent the formation of smoke, also water gauges fitted with glass tubes in duplicate steam pressure gauges, check, feed and blow-off valves and duplex safety valves.

DISCUSSION.

Mr. HUGO BILGRAM:—The advantages of high pressure have been very clearly shown by the speaker, but I think it proper to say that there are practical limits to the application of high pressure. The statement is made that the highest economy would be reached by expanding down to a perfect vacuum. This is only correct when we disregard the resisting forces of friction; but as we cannot run an engine without having to overcome that resistance, there is a limit to the advantage gained by further expansion. This limit is reached when the pressure of the steam on the piston equals the average rate of friction reduced to the surface of the piston. Therefore we have on the one hand a limit of the use of expansion. A similar limit can be shown to exist on the high pressure side of the diagram. The highest pressure is applied just when the crank is near its centre, where the motion of the shaft is greatest in proportion to the motion of the piston. The attending friction consumes a considerable percentage of the power, and since for a higher initial pressure the diameter of the crank shaft must be increased, the consumption of power by friction from this cause will increase even more rapidly than the rate of the initial pressure. These limits may be determined by practical tests, or else by intricate calculations, but it is my impression that we use the steam in the present high pressure engine very near to these limits, especially in the compound engines, where high and low pressure cylinders are combined.

Mr. LE VAN:—In reply to Mr. Bilgram, I would state that in practice we have been able, with a condensing engine, using high pressure steam to realize 90 per cent. of the theoretical diagram with the consumption of from 15 to 18 pounds of water per hour per horse-power. This cannot be done with low pressure steam. It is an every day occurrence in this city, with high pressure automatic engines without condensing to average 85 per cent. of the theoretical diagram. At the electrical exhibition some experiments made with this boiler, which supplied steam to what is known as the "Buckeye Automatic Engine," developed a horse-power with 26 pounds of water per hour. At the boiler trials during the Centennial exhibition, we thought it extraordinary if we produced a horse-power with 30 pounds of water. The difference between the two trials is that in the former we carried 100 pounds per square inch, whereas in the latter we carried but 70 pounds; therefore, in the last eight years we have decreased the consumption as twenty-six is to thirty pounds of water per hour per horse-power; so, independent of all the objections which Mr. Bilgram so forcibly stated, there is no doubt we have been able to realize a result of 90 per cent. I think, therefore, that high pressures have proved desirable.

Mr. HUGO BILGRAM:—I did not intimate that the high pressure of, say 100 lbs., as now used, instead of 60 lbs., would not be an advantage, nor did I intend to convey that impression. I meant to show a final limit to the efficiency gained by an increase of pressure. I admit that it may be possible that 120 lbs. instead of 100 lbs. are capable of giving still better results, but finally we must reach a limit beyond which we can gain no more.

DAILY CYCLE OF SOLAR MAGNETIC INDUCTION.—M. Quet considers that the induction produced by any system of electric currents, upon a particle *m*, of positive electric fluids, is perpendicular to the relative velocity, *ov*, of this particle, and to the direction, *od*, of the line of force which passes through the point, *o*, of the magnetic field. If f designates the force, and e represents the angle *vod*, we have $f = mdv \sin. e$.

The induction of the sun upon the mass, *m*, placed at the centre of the earth, will be directed toward the centre of the sun, or towards that of the earth, according as the electricity is positive or negative, or according as the austral magnetic pole of the sun is at the north or south of the ecliptic. For all other points of the earth the analogous forces will be sensibly equal and parallel to the foregoing. At each instant the electric fluids of the globe are therefore submitted to two systems of forces, one converging towards the centre of the sun, and the other towards the centre of the earth. Hence arise two cycles of magnetic variation, one having a mean solar day for its period, the other the synodic rotation of the sun around its axis.—*Comptes Rendus*, Oct. 20, 1884. C.

FURTHER EXPERIMENTS IN WEATHER FORECAST.

By Pliny Earle Chase, LL.D.

Since the early part of February, I have received from the Signal Service Bureau the tri-daily weather reports, as well as the daily weather maps. I have also extended my comparisons to Caswell's Meteorological Observations at Providence, from December, 1831, to May, 1860. The reports, the maps, and the comparisons, all show that the Haverford tests, in my "Experiment in Weather Forecast" (this Journal, April, 1885), are by no means exceptional, but that similar results are probably attainable in all parts of the United States. I therefore venture to formulate some of the principles of astronomical weather forecast, as follows:

1. The lunar modifications of barometric pressure tend to produce, *a*, high barometer and westward pressure at syzygy; *b*, low barometer and eastward pressure at quadrature; *c*, falling barometer between syzygy and quadrature; *d*, rising barometer between quadrature and syzygy.

2. The solar modifications, through the combined action of heat, attraction and "relative motion," tend to produce, *a*, high barometer and southward pressure at the octants before syzygy; *b*, low barometer and northward pressure at the octants after syzygy; *c*, falling barometer between *a* and *b*; *d*, rising barometer between *b* and *a*.

3. The influences may be most equally divided by counting as fair all weather which is either fair or clearing, and by counting as stormy all weather which is storm-breeding (including "pet days"), lowering or stormy.

4. Precipitation, during stormy periods, produces a partial vacuum, which is often supplied by an inrush of dry air, producing pet days.

5. The exceptional storms or stormy tendencies, during the prevalence of fair indications, are mostly anti-cyclonic in their origin.

6. The general tendencies, independent of local and monsoon influences, are, *a*, fair for the octants following quadrature; *b*, variable, with predominant anti-cyclonism, for the octants preceding syzygy; *c*, stormy for the octants following syzygy; *d*, variable, with predominant cyclonism for the octants preceding quadrature.

7. The tendency to increasing dampness is greatest, *a*, from the Atlantic Ocean, between two days before and three days after syzygy,

with a prevalence of anti-cyclonic currents; *b*, from the Gulf of Mexico, between two days before the first and fifth octants and one day before quadrature, if cyclonic currents prevail; *c*, from the Lakes, between quadrature and syzygy, when the prevailing currents are anti-cyclonic.

8. The reversals of tendencies are mostly due to long continued polar or equatorial currents. These currents are not apt suddenly to change their character. Therefore, by watching all the influences, sufficiently to see which are normal and which are abnormal, it becomes possible to make forecasts for two or more weeks in advance, which will be verified in four cases out of five.

9. The relations of the daily to the annual barometric oscillations, which were used in 1863 as a ground for estimating the Sun's distance ("Proc. Amer. Phil. Soc.," ix, 283-8; x, 375-6), seem to account for an average daily eastward movement of about 1° in monsoon influences, which has been pointed out by L. A. Sherman, editor of the "Port Huron Times" ("Amer. Meteorolog. Journal," Nov., 1884; "Port Huron Daily Times," Feb. 11, 1885).

The following summary shows the influences, for an entire month, which may be looked for between May 15 and June 15, 1885. It will give readers of the JOURNAL an opportunity to judge for themselves to what extent these influences may be used as a basis for forecast. Observers will confer a favor by communicating the results of their observations to the Secretary of the Franklin Institute.

May 15-17, May 28-June 1, June 12-15, 1 *c*, 2 *c*, 3 (stormy), 4, 6 *c*, 7 *a*, 7 *b*.

May 18-21, June 1-5, 1 *c*, 2 *d*; 6 *d*, 7 *b*.

May 21-24, June 5-8, 1 *d*, 2 *d*, 3 (fair), 5, 6 *a*, 7 *c*.

May 25-28, June 8-12, 1 *d*, 2 *c*, 6 *b*, 7 *a*, 7 *c*.

On account of the friction of surface winds, the influence of accelerating and retarding pressures (1, 2), is most often shown by the upper currents, when cirrus clouds are visible.

LIGHT CLOUDS OF THE UPPER ATMOSPHERE.—A. Badoureau supposes that in the upper regions of the atmosphere the temperature may be reduced nearly to absolute zero, and although the temperature is correspondingly reduced he thinks it probable that carbonic acid, nitrogen and oxygen may be there condensed into clouds analogous to those which are formed by watery vapor in the lower atmosphere.—*Comptes Rendus*, Oct. 20, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 7.—Drawbaugh's Telephonic Inventions.

(Concluded from page 331.)

As we have already stated, the apparatus just described belonged to the class of electro-magnetic telephones, or those in which the voice of the speaker is caused to vary the electrical resistance of a circuit in which is placed a voltaic battery or other electrical source. The electrical current, so modified, being transmitted to the further end of the circuit, reproduces the speech by the use of some suitable receiver.

Drawbaugh's next step in the invention of the telephone would appear to have been made some time late in 1869, or early in 1870, when he claims to have constructed another form of electro-magnetic receiver. This apparatus, which is shown in Fig. 8, is of interest from the fact that when afterwards modified so as to act as a transmitter as well as a receiver, it formed his first magneto-electric telephone.

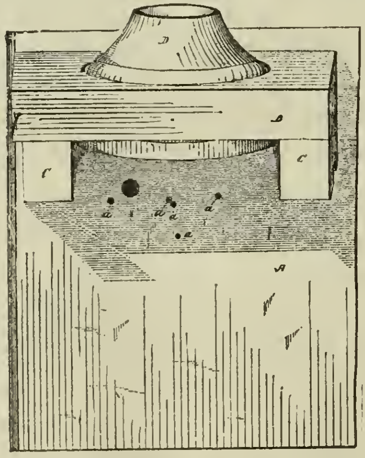

Fig. 8.—Drawbaugh's Electro-Magnetic Receiver.

Fig. 8 shows the instrument in its original form as an electro-magnetic receiver.

To the upright board *A*, which served as a support to the instrument, the blocks *C*, *C*, are firmly secured at right angles, and serve as a support for the board *B*, through the centre of which the mouth-piece *D*, and the parts connected therewith pass. These parts were contained in the cylindrical box seen in the figure. Front and rear elevations of this apparatus are shown in Fig. 9, and a sectional view in Fig. 10.

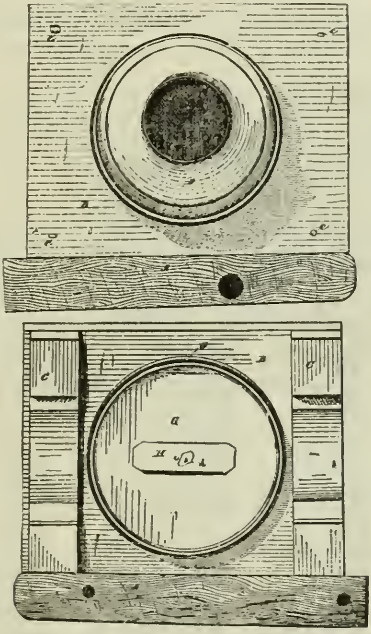

FIG. 9.—Front and Rear Elevation of Drawbaugh's Receiver.

The aperture of the mouth-piece was constructed as shown in Fig. 9, at *D*. Two diaphragms were employed in this receiver. These were placed parallel to each other, as shown in Fig. 10, at *E* and *G*.

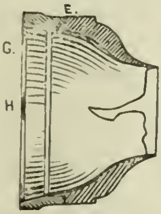

FIG. 10.—Section through Receiver.

These diaphragms were connected together by a cord attached to their centres. The diaphragm, *G*, furthest from the outside of the mouth-piece, was provided with the armature *H*, placed in the position shown. An electro-magnet was suitably supported with its poles near the armature, but not in contact therewith. The additional or accessory diaphragm, the one nearer the ear of the listener, or the one that was unprovided with an armature, was pierced with a number of holes. This instrument was placed in the circuit of a battery and the tumbler instrument already described.

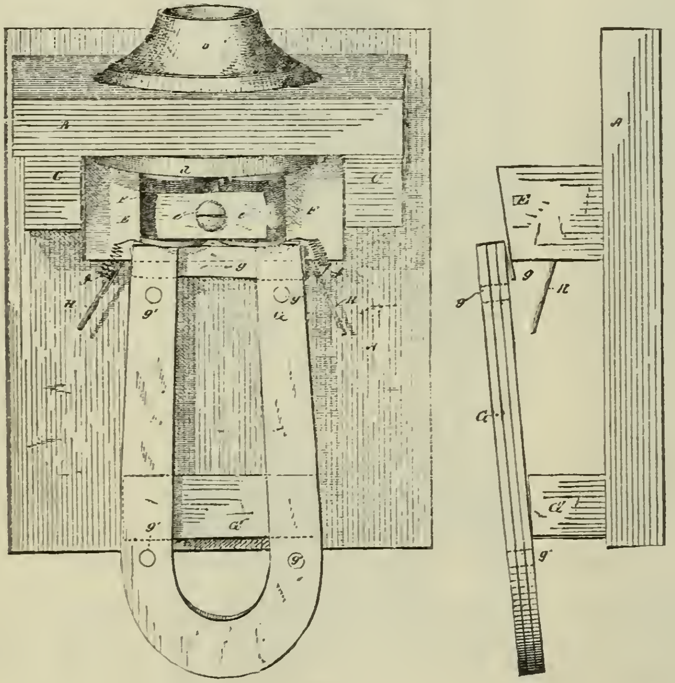

FIG. 11.—Drawbaugh's Magneto-Electric Telephone.

Drawbaugh appears to have modified this instrument shortly afterwards as follows; viz., he removed the accessory diaphragm and replaced the main diaphragm by a thin plate of German silver, to the centre of which was attached the armature *H*, as before. The interest in these instruments centres in the modification he claims to have made in the electro-magnet; for, removing the bar that connected the two cores, he joined them by means of a permanent magnet of horse-shoe form. The instrument, thus modified, became capable of being used as a transmitter, as Drawbaugh claims to have discovered during his experimentation. Most of the parts of the instrument, as originally made, are, it is claimed, still in existence, and were produced in the famous interference suit already referred to.

The details of the apparatus, when in condition for use as a telephone transmitter as well as a receiver, are shown in connection with Fig. 11.

The base *A*, supports *C*, *C*, and *B*, and the mouth-piece *D*, are the same as shown in the last figures. The electro-magnet seen at *F*, *F*, is held in the position shown by means of the brass plate *e*, *e*, screwed to the base *A*. The piece of iron joining the lower poles of the electro-magnets *F*, *F*, is in this apparatus replaced by the permanent horse-shoe magnet *G*. This magnet was placed in the position shown with its poles in contact with the lower poles of the electro-magnets. g, is a piece of paper, and G^1, a block of wood on which the permanent magnet rests. Their relative thickness is seen in the side elevation shown on the right. The permanent magnet was of the compound type, united at g^1, g^1, g^1, g^1. The terminals of the coils of the electro-magnet are shown at *H*, *H*. The German silver diaphragm was held in place by means of the band *d*.

Assuming that the date of construction of this instrument can be established, then it not only anticipates Bell's patent of 1876, in showing a contrivance whereby the armature of an electro-magnet is set into vibration by the voice, and thereby produces undulations in the currents traversing the coil of the electro-magnet, such currents being in the same circuit with an apparatus capable of receiving them and correctly reproducing the original speech, but it also anticipates the essential claims of Bell's patent of 1877, since it shows means whereby the movements of a plate of inductive material before a permanent magnet with coils on the end of the magnet nearer the plate, can produce undulations in an otherwise continuous current traversing its coils, or can produce undulatory currents therein, although no currents were originally present.

Another instrument, made, as claimed, some time during 1871, was, like the preceding, originally designed for use with a voltaic battery as a receiver, but was afterwards provided with a permanent magnet, when it became operative as a transmitter and was employed by Drawbaugh as such. These latter changes appear to have been effected prior to July, 1873. This instrument was used in connection with the magneto-electric apparatus just described, and as might have been supposed, gave much better results than were attained by the use of the cup or tumbler transmitter, and the earlier form of electro-magnetic receiver already described.

The details of this apparatus while used as a receiver only is shown in Fig. 12.

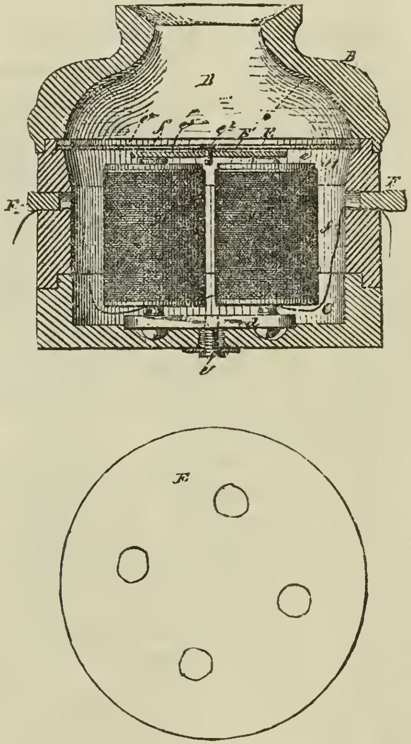

FIG. 12.—Drawbaugh's later Form of Receiver.

The mouth-piece, at *B*, has a comparatively wide air space between its open end and the diaphragms, of which latter there are two. The upper diaphragm, which is shown at *E*, was perforated in the manner seen in the lower part of the figure. The lower diaphragm, E^1, had an armature, *e*, attached to it by means of the screw e^2. This armature faced the poles of the electro-magnet *D, D,* and was near said poles but not in contact with them. A screw, e^1, holding the connecting bar *d*, apparently served for the adjustment of the magnet poles with respect to the armature. The wires of the electro-magnet passed out of openings in the case or box holding the instrument, and were held in position by means of the plugs *F, F.*

The modification of the instrument, whereby it acquired the power of acting as a transmitter as well as a receiver, is shown in Fig. 13.

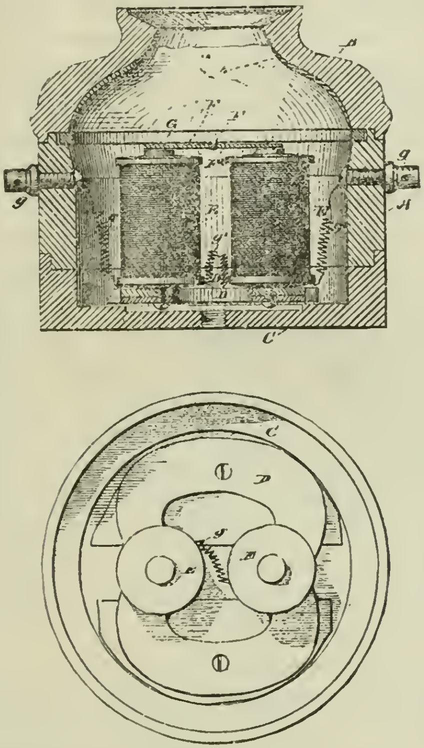

FIG. 13.—Drawbaugh's later Magneto-Electric Telephone.

In this case the upper perforated diaphragm is suppressed, apparently because it failed to produce the beneficial results anticipated. The air space in the mouth-piece above the diaphragm was not modified at first, but subsequently considerable modification was effected in the shape and dimensions of the diaphragm, which was, as we have seen, the case with the later tumbler transmitter. The great change, however, as we have already intimated, consisted in the replacement of the connecting yoke *d*, of the last instrument, by permanent steel magnets, thus changing the apparatus into a magneto-electric telephone. This was effected by the disposition of permanent magnets, shown in the lower part of Fig. 13, where two curved steel magnets, *D*, have their similar poles opposite one another and joined by the soft iron cores of the electro-magnet *E, E.* In this manner the cores of the magnet *E, E,* become permanently magnetized by induction from the poles of the steel magnet, thus permitting the instrument to act as a transmitter. For it is evident that the movements of the armature F^2, attached to the diaphragm *F,* would produce in the coils of wire on *E, E,* currents that would increase or decrease the current passing through them, and thus give it an undulatory character.

Some of the diaphragms employed by Drawbaugh, about the time of the construction of these latter instruments, were corrugated. It appears that the metal employed for diaphragms was too thin and required to be dampened. This Drawbaugh sought to effect by increasing the stiffness and rigidity by corrugation.. Edison, it will be remembered made a similar improvement of the diaphragm in his instruments by constructing it of very thick metal. Drawbaugh claims that he obtained greatly improved results by this means.

The testimony as to the actual existence of these instruments appears to be exceedingly strong. Apart from the testimony of Drawbaugh, over forty independent witnesses testify to having seen the instruments in Drawbaugh's shop prior to June, 1875. The limit of the latter date is unquestionably fixed by the fact that fourteen of these witnesses, who either remember seeing and actually speaking through these instruments in Drawbaugh's shop, testified that they were never again in his shop after June 2, 1875.

The next instrument constructed by Drawbaugh, some time before December 23, 1874, at which time an axle company was started that did business in Drawbaugh's shop, is one of the first instruments made by him which he has preserved intact. This form is shown in Figs. 14 and 15, in longitudinal sections, and in front, rear, and side elevations.

In Fig. 14 is seen a front view of the instrument with the cap removed, and also views of the upper and lower sides of the diaphragm.

A, represents a hollow circular chamber provided with a thin wooden diaphragm *C,* securely kept in position by means of the cap *B.* An electro-magnet *D, D,* has its holes projecting into the hollow chamber *A,* and is supported by means of the brass bracket *F.* Opposite the holes of the magnet is the armature *d,* secured to the lower side of the diaphragm *C.* A brass screw B^1, passing through the front of the cover presses against a piece of soft rubber *c,* placed at the upper side of the diaphragm *C.* This piece of rubber was designed to act as a kind of dampening pad, to prevent the too free vibration of the diaphragm. A mouth-piece at *I*, was provided near the upper part of the diaphragm. The screw *G*, passing through the bracket *F*, served to adjust the position of the bracket, and hence the position of the electro-magnet *D*, *D*.

As originally constructed, the mouth-piece was placed opposite the middle of the diaphragm. With this disposition of parts the diaphragm was found to vibrate too freely, and the opening was shifted to the position shown in the figures, and the dampening pad placed against the centre of the diaphragm. These changes were made about a year after the instrument was first constructed. This instrument, it will be observed, has no permanent magnet.

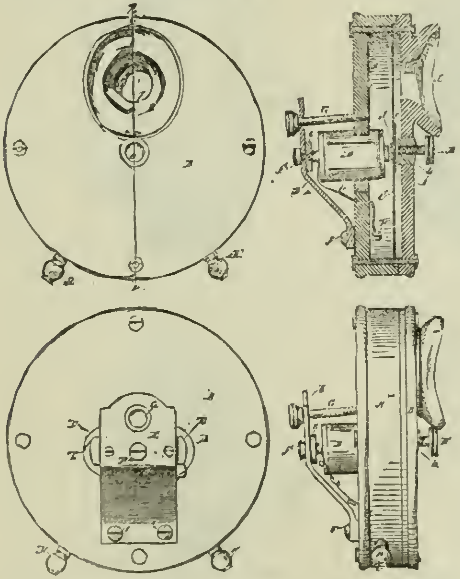

FIG. 14.—Drawsbaugh's Telephone, constructed prior to Dec. 23, 1874.

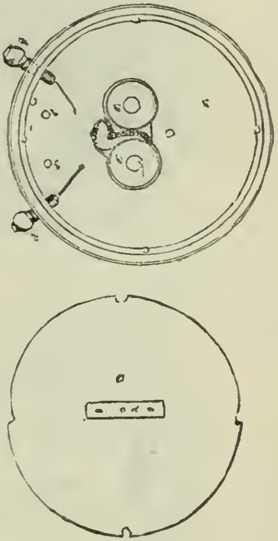

FIG. 15.—Drawbaugh's Telephone constructed prior to Dec. 23, 1874.

As to its efficiency, it is declared by an expert of undoubted ability to be an operative instrument, or "a highly organized magneto-receiver, with a neutral magnet."

Concerning its actual existence at the time claimed by Drawbaugh the evidence in this remarkable case appears to be almost overwhelming, unless it be assumed that the witnesses are deliberately perjuring themselves. This, however, their well known character renders extremely improbable. No less than forty-four witnesses testify to having seen the instrument in Drawbaugh's shop prior to the date of Bell's first patent, viz., February 14, 1876, of this number, thirty-two testify to having seen the apparatus prior to June 2, 1875, and sixteen of these prior to January, 1875.

As to its practical value, fifteen witnesses testify to having actually employed, in Drawbaugh's shop, the apparatus just described for the reception of articulate speech, prior to February 14, 1876; and since some of these latter testify that they were never again in Drawbaugh's shop since June 1, 1875, the date of actual use would appear to be thus carried back prior to June, 1875.

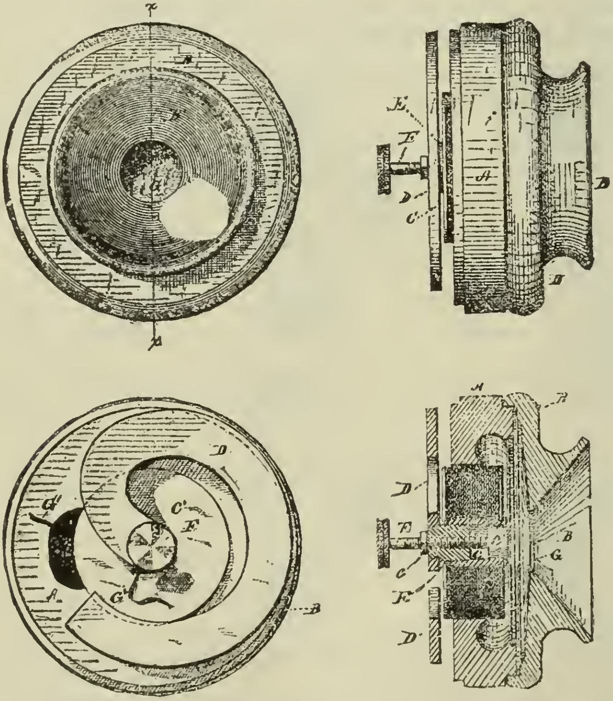

FIG. 16.—Drawbaugh's Magnetic-Electric Telephone of 1874–1875.

It will be noticed that the three different forms of apparatus we have just described as following the original cup and tumbler transmitter, and the original electro-magnetic receivers, were variations of receivers. Although it is true that the introduction of permanent steel magnets in most of them permitted them to be used as transmitters as well, and thus marked an era of great improvement, yet the effort appeared to be directed mainly to the improvement of the receiving part of the apparatus. Nor does the order of this development appear at all improbable. Having by the construction of the cup or tumbler instruments produced a highly efficient form of transmitter, he naturally turned his attention to the construction of forms of apparatus suitable for use in connection therewith. This would appear to us the natural order, and as we have already seen was the order followed by many of the other inventors in telephonic apparatus.

The next set of telephones, claimed as invented and constructed by Drawbaugh, appear to be of the magneto-electric type. Parts of these instruments were made by Drawbaugh himself; the remaining parts were made under his instructions. These instruments appear to have been made in the latter part of the winter of 1874, and early in 1875. The original instruments are still in existence. The party who aided Drawbaugh to construct them testifies that he could at any time, from early in 1875, up to the present (1884), have reproduced these machines, except, perhaps, the proper proportions as to size of different parts.

One of these instruments is shown in front and side elevations at the top, and in rear and side elevations at the bottom of Fig. 16.

The wooden casing *A*, of the instrument, is provided with a cap *B*, and mouth-piece B^1. A diaphragm *G*, of tinned iron is securely fixed in a recess at the upper edge of *A*, and held in place by means of the cap *B*.

An electro-magnet *C*, consisting of a single hollow core *c*, is fixed in the position shown in an opening in the rear of the casing *A*, of the instrument. Soft iron plugs c^1, and *E*, pass through the hollow core of the electro-magnet. The plug c^1, is attached to the end of the adjusting screw *F*, by means of which it is readily moved towards or from the tinned iron diaphragm. The plug *E*, serves to support the screw *F*. A small jam nut *e*, is provided for holding *F*, firmly in place when once adjusted. The permanent magnet *D*, shaped as shown, has one of its poles securely connected to the rear pole of the electro-magnet *C*. This apparatus was therefore capable of use both as a transmitter and as a receiver.

The other magnet-electric instrument of 1874–1875, is shown in front and side elevations at the top, and in rear elevations (cap off) and in section at the bottom of Fig. 17.

This instrument, it will be observed, is similar in its general construction to that just described. It differed, in that it was provided with a rear cap *C*, which encased the permanent magnet and adjoining parts. An aperture *h*, through the centre of the cap, permitted the the regulation of the movable plug through the adjusting screw.

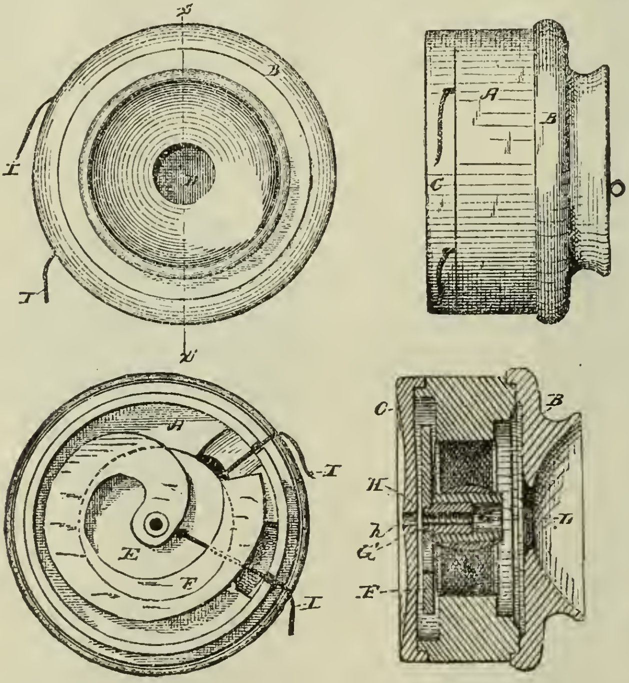

FIG. 17.—Drawbaugh's Magnetic-Electric Telephone of 1874-1875.

Concerning the operation of these instruments, a well-known expert, appearing for Drawbaugh in the previously-mentioned suit, testifies as follows:

"The instruments '*D*,' and '*E*,'" (those we have just described in connection with Figs. 16 and 17), "show the magneto-telephone in as compact a form as it has ever been constructed up to the present time. The magnet is flattened and curled, so as to occupy the least possible space; the means of adjusting the distance between the core and diaphragm is simple, positive, and easily controlled; and the instruments themselves, as I have proved, are excellent working speaking telephones on a circuit without a battery. They embody all the elements going to make up a speaking telephone, as described in Bell's two patents in suit. And, in fact, I see no reason why, if these machines were now manufactured and were upon the market, they would not, so far as form, construction and and operation are concerned, successfully compete with any form of magneto-telephone now in vogue."

So, too, the witness for the complainants in the same suit, a well-known expert, testified after a trial of one of the instruments, the one described in Fig. 17: "I think that instruments like *E*, might be successfully employed for practical use, especially if there were no better ones to be had. The articulation of *E*, seemed to be very good, but the sound was wanting in volume and loudness."

Assuming that the above instruments were actually constructed at the date claimed, it will appear that Drawbaugh had, at that comparatively early day, made a progress in the improvement of the telephone that seems almost marvelous, and which it would be difficult to regard as probable were it not for the extent and nature of the testimony, both independent and corroborative, concerning the apparatus in question. For, it appears by the printed testimony, that some twenty-seven witnesses, independently of Drawbaugh himself, testify to have seen these instruments at some time prior to February 14, 1876. Most of them, indeed, testify to have seen them before June 2, 1875, and many of the witnesses claim to have actually talked through the apparatus, transmitting and receiving intelligible speech thereby. It is difficult to believe that so many independent witnesses could all be mistaken concerning the same thing, and it is equally difficult to believe that they could be testifying falsely, so that it would appear that the instruments were made at the date claimed.

The fact that Drawbaugh, supposing his claims to be true, had at so early a date a highly organized instrument, capable of such extended and valuable commercial applications, without ever even patenting it, or obtaining for it a wider notoriety, naturally suggests grave doubts as to the probability of the actual truth of the facts as claimed. It should be borne in mind, however, in Mr. Drawbaugh's behalf, that a considerable time elapsed after Mr. Bell brought the articulating telephone into general public notoriety, before its real value or practical applications were thoroughly appreciated. So little, indeed, did Mr. Bell appear to think of that portion of his application of February 14, 1876, which is claimed to cover the principle of the electrical transmission of speech, that nowhere in said specification does he clearly express the fact that it was one of the objects of his invention to transmit speech electrically. The failure of Mr. Drawbaugh, therefore, to patent his inventions, or to bring them into general public use, though naturally suggestive of doubt as to the probability of his having actually made the inventions at the time claimed, yet the doubt thus suggested is by no means conclusive as against Mr. Drawbaugh. Such doubts, it may be added, are, it would seem, almost, if not entirely removed, by the apparently overwhelming evidence as to the correctness of Mr. Drawbaugh's assertions.

It may be remarked that, apart from the testimony as to the inventions of Mr. Drawbaugh, which we have thus briefly described, there would appear to be no internal evidence of improbability arising from the order in which he claims to have evolved them. Their order of evolution appears to be quite natural, as we think the following shows.

The early experiments begin with varying resistance transmitters as are illustrated in the old tea-cup instruments. In this respect he begins where, in the opinion of some, Reis left off, and where Edison began his experimental work in telephony. The step taken by him in obtaining experimentally the best conditions for success in this direction would appear to us to show no little skill and intelligence as an investigator. He followed, at that early day, substantially, the steps afterward independently taken by Edison in the development of his carbon transmitter, and produced an instrument substantially like it. His early form of electro-magnetic receiver, crude and awkward at the start, with its membraneous diaphragm, string connection, and the spring support for the armature, gradually gave place after repeated trials to the single metallic diaphragm, with the diminished air space on the side brought next to the ear.

Then follow his later magneto-telephones, suggested most probably by trying to use his receivers as transmitting instruments. His early forms were naturally crude, and the parts inconveniently assembled. The fact that so much of them was exposed led to their being frequently put out of the adjustment necessary to their efficient operation. He therefore produces a more compact instrument, and encloses it in a suitable case. Experimenting with large diaphragms, probably with the idea of obtaining greater strength of the sounds, he experiences difficulty in false vibrations, and avoids them by the device of placing the mouth-piece out of the centre of the diaphragm, at which place he puts a dampening pad. Finally, however, he realizes that no advantage is to be derived from large diaphragms and he produces the exceedingly compact and efficient instrument shown in Fig. 17.

Besides the apparatus we have described, all of which are claimed to have been produced prior to the date of Bell's application for Letters

Patent, viz., February 14, 1876, Drawbaugh subsequently produced numerous other instruments, similar to many of those now in general commercial use. Since, however, we are at present interested mainly in the early history of the telephone, the instruments already described will be sufficient to enable the reader to appreciate the exalted position that Mr. Drawbaugh claims to occupy in the history of the articulating telephone.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, March 13, 1885.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April* 15, 1885.]

HALL OF THE INSTITUTE, April 15, 1885.
Vice-President, FRED'K GRAFF, in the chair.

Present—282 members and 75 visitors.

The election of ten new members since the last meeting was reported.

The Chairman of the Committee on Science and the Arts reported that the Committee recommend the award of the "John Scott Legacy Premium and Medal" to C. J. H. WOODBURY, of Boston, for his apparatus and system of securing safety in the Use of the Electric Light in Mills, etc., and to CHRISTIAN E. METZLER and JOHN H. BURRELL, JR. of Philadelphia, for their improvements in Signal-Lanterns for Railways.

The recommendations of the Committee were approved, and the Secretary was directed to report the action of the Institute to the Board of City Trusts.

Prof. WILLIAM H. GREENE exhibited by projection on the screen some curious and interesting experiments illustrating the continuity of the liquid and gaseous states of matter.

The apparatus consisted of a series of glass tubes containing carbon dioxide under very great pressure. At temperatures below 87°F. the tubes contain the substance as a liquid, but above 88° no amount of pressure will cause the gas to become liquid. At 87·7°, and under a pressure of 73 to 75 atmospheres, it is in a critical condition, in which the attractive force of the gaseous particles is exactly balanced by the repelling force of heat, and the least lowering of temperature causes an imperceptible transition to the liquid state.

Col. WILLIAM LUDLOW, Chief Engineer of the Water Department of Philadelphia, then gave, by request, his views respecting the Future Water Supply of the City. The subject was freely discussed by Prof. E. J. HOUSTON, FRED'K GRAFF and HECTOR ORR. The report of the same has been referred for publication.

At the close of the debate, the following resolution was unanimously adopted:

Resolved, That the thanks of the meeting be given to Col. LUDLOW for his interesting and valuable remarks, and that the FRANKLIN INSTITUTE is in full sympathy with him in his efforts to improve the quality of the Water Supply of the City of Philadelphia.

The Secretary's report embraced an account of progress made in the work of preparing for the forthcoming "NOVELTIES" Exhibition of the Institute; a technical description of the principle and operation of the Phelps System of Telegraphing to and from Railway Trains in motion and some descriptive remarks (illustrated by photographic views from E. L. WILSON'S Collection) upon the New Orleans Exhibition.

The Secretary stated that the Institute had been invited by the Society for the Encouragement of the Arts, Manufactures and Commerce, of London, England, to nominate a suitable person, or persons, to receive the award of the "ALBERT MEDAL" of the Society, which is awarded annually for "distinguished merit for promoting arts, manufactures or commerce." The Secretary added that the Committee to which this agreeable duty had been confided would be pleased to receive suggestions from members of the Institute.

Adjourned. WILLIAM H. WAHL, *Secretary*.

DEVIATIONS OF THE PENDULUM IN MEXICO.—During the stay of the French Commission at Fort Loreto, in Puebla, M. Bouquet de la Grye installed, in the chapel of the fort, a seismograph, composed of a pendulum and a multiplying balance. After freeing the observations from abnormal movements, he found that the sun repelled the pendulum in the morning and evening, but at midday, its influence was attractive. The vaults of the chapel, which ran from S. W. to N. E., being heated at morning and evening, thrust the pendulum in a direction opposite to that of the sun, in the middle of the day, the influence was reversed. In grouping the observations under lunar hours, the pendulum was found to be attracted by the moon. The seismograph showed that there were frequent abnormal movements of the pendulum, there being twenty-two oscillations of the ground. The mean movements were in the direction of N. W., S. E., which is the same as that of the chain of the volcano Popocatapetl. While the oscillations were going on, the inhabitants of Puebla felt but a single earthquake shock. It would be interesting to extend these observations, by registering the movements of a long pendulum for a considerable period in an observatory; they would furnish valuable data respecting the movement of the earth's crust and the tidal phenomena.—*Comptes Rendus*, July 28, 1884. C.

A FRUITFUL GRAIN.—A grain of wheat sown by the wind grew without cultivation in the midst of a meadow at Chatillon-sur-Chalaronne. On cutting the hay the tuft was left undisturbed and allowed to ripen. At harvest time it was found that the single grain had produced 53 stalks, 43 of which bore fine heads, yielding a total harvest of 1,563 grains.—*Les Mondes*, Sept. 18, 1884. C.

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THE WORLD'S INDUSTRIAL AND COTTON CENTENNIAL EXPOSITION.

BY DR. PERSIFOR FRAZER.

The city of New Orleans occupies a section of low ground lying between Lake Pontchartrain on the north and the Mississippi river on the south; but the latter is a very irregular boundary line, of which the general course within these limits is easterly, with the usual meanderings to the north and south which almost everywhere characterize the Father of Waters.

There has been an evident effort to follow the course of the river in a series of streets which extends back in a line perpendicular to its banks for nearly a mile; but after that distance the parallelism becomes less and less rigorous, until finally the lake's shore gives the direction to the thoroughfares. The manner in which these two systems blend into each other is quite interesting, and reminds one of the gradual transition of curves to a straight line which is so often seen in the folds of thick masses of rocks, and may be produced artificially by bending in different directions a thick bundle of sheets of paper.

It would take too long to describe all the features of the exposition grounds, with the exact bearing of one point from another. In general terms, the grounds are about half a mile long (east of north and west of south) and a quarter of a mile in a direction transverse to this. These distances are merely rough guesses, rendered necessary from the fact that there is no scale of feet on the map of the Exposition and grounds which has been issued for the use of strangers, by the Department of Installation under the direction of Mr. Mullen. The distances which I have given are probably too small.

The main building is of wood, painted a subdued pink somewhat like the sides of the International Electrical Exposition building in Philadelphia. It is somewhat larger than the main Exposition building of the "Centennial," by reason of a greater width. It is not easy at the first glance to say which is the length and which the width of the New Orleans main building. Viewed from the top of one of the towers, it presents the appearance of a group of separate wooden roofs, of which the eaves touch, and all have been exposed to the same snow storm. In fact, to make them water-tight, the roofs have been smeared with tar (or some similar substance) and then covered with paper boards, which have again been coated with the same material. The whole has been treated when dry to a partial whitewashing; but this part of the operation has not been thoroughly carried out, and the whitewash only appears in large spots over the surfaces. The first impression which a sight of these roofs makes upon the stranger is their great danger from fire. Of course in such an Exposition there are numerous fires, which send forth from their chimneys the usual products of soft coal, which is the universal fuel, *i. e.*, heated smoke and frequent sparks. It would seem that any sparks falling on the inflammable material which constitutes the roof, might easily set it into a blaze; and if this were done, its extinction would be almost impossible.

North of the main building is the so-called "United States Building," in which there are many very interesting exhibits, arranged with some system. Between the two, and near the western limit of the grounds, are three long low sheds (or, properly speaking, four, since the southernmost of the series consists of two parallel and independent sheds), each about 430 feet from end to end. These are designed for exhibits of stock of all kinds, but at present* are hardly occupied. The middle of the three contains 60 stalls on a side, each stall being about six feet in width. At present there are a couple, each, of Suffolk, Cheshire, Duroc, Jersey and Berkshire hogs, all exhibited by Mr. J. B. Mead, of Randolph, Vt. The southern half of the westernmost of the two southern sheds contains a very interesting, but not very large, collection of cotton. The specimens were principally from Louisiana and South Carolina, though other districts were represented. The northern half of this shed contained a few cattle and horses, which either were not intended as an exhibit, or were the unreclaimed part of a cattle exhibit which had been held there previously. The easterly of the two sheds contained the remains of a bench show of dogs—a not very numerous remainder.

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* March 8 to 20.

These outlying buildings, with a furniture building to the east of them and near the eastern extremity of the grounds, the Art Gallery; two long and slender sheds which stretch to the south of the main building and are called the Machinery Buildings; a separate wooden pavilion bearing the name of the "Department of Public Comfort," but in reality containing only a rather modest restaurant; a beautiful pagoda built by the Mexicans, but not yet occupied by their minerals, to which it is dedicated at the period when these notes were taken; and the long narrow green-house which is called Horticultural Hall: these comprise all the buildings located on the grounds.

The means of transit are either by one-mule car, on St. Charles street or Magazine street, or by steamer, or by private carriage, at $5. To these the writer, in spite of the expostulations of some kindly disposed natives, added a fourth, viz., by walking. The distance from the centre of the main building to the centre of New Orleans, or to the corner of St. Charles and Canal streets, was said to be about seven miles, and this estimate is not very far out, to judge by the time of walking it. By far the most agreeable way to get to the exposition, however, is by the steamer, which takes about ¾ hour to go, and 25 minutes to return to the levee at the foot of Canal street. By this means one is always assured of a seat and of the cool breezes of the river, which are not to be scorned, even in mid-winter.

On landing at the exposition grounds one is confronted by a species of wooden gate-house, of a pinkish color, in the form of the turreted castles which generally form part of a child's Noah's Ark, but this real one (which is larger than those) must have been divested of one wing. In striking contrast with this nightmare of the lumber yard, is the neat cottage building which, lying a short distance to the left, shelters the two handsome Worthington pumps. These supply the Exposition with water, each of a capacity of 1,000,000 gallons (3,785·21 cubic meters or tonnes) of water per diem.

About 150 meters or yards north by east of the landing are two sheds, which contain machinery, of which one is open and the other covered, and both connect with the main building. To the west of these are two small structures, designed to illustrate the methods employed to dry timber. That one which is nearest to the landing is the "Excelsior and Chicago" dryer; the other is the "Invincible." The principle employed in both seems to be the same, *i. e.*, a heating apparatus below a small frame building, in which latter the boards to be dried are so stacked as to allow the hot air produced by a system of steam pipes to pass in succession over every part of the material.

The Mexican exhibit in the long greenhouse, as elsewhere, was fine in what was shown, but the varieties of Mexican plants which might have been expected were not to be found. The Maguey plant and the cactuses, however, were very interesting. The other exhibits were surprisingly meagre, in spite of the manifest advantages which its climate conferred on New Orleans for such a display. Colorado, Wisconsin and Iowa had collections of apples, which probably had been once good, but when viewed were all more or less rotten. Florida showed the shaddock, oranges and lemons. Louisiana and Kansas also had exhibits which were fair in comparison with the rest; but it must be confessed that the general impression left upon the mind here is that of disappointment.

The easternmost machinery wing, which has been already alluded to, is built of corrugated iron, and bears the name of S. C. Forsaith, Manchester, N. H. Both of these wings are about equal in length, *i. e.*, 100 meters or yards, and each has a width of about 20 meters or yards.

The cotton press of S. B. Steis and others challenged the first attention, and the exhibit of George V. Cresson, of the Philadelphia Shafting Works, was worth a careful examination. It should have been said that in front, or rather on the river side of the entrance to the machinery annex, stands a small kiosque, containing the exhibit of the "Diamond Prospecting Company," which is the agent for the Sullivan diamond drill. The exhibit shows a portable engine, with lowered smoke stack, attached by steam pipes to the drill, which latter, however, at the times of several visits, was not in operation. The advantage claimed for this machine is that it employs a single hydraulic cylinder, with the drill rod carried up through the piston rod, instead of the two cylinders, with the drill rod outside, or of "an objectionable positive feed." An additional advantage is that whereas other drills are sold subject to such onerous conditions that the purchaser hardly knows what rights he has acquired by the purchase, the owner can do what he chooses with the Sullivan drills, and sell them whenever he is so disposed. The "A" machine drills a hole, 1$\frac{3}{4}$ inches in diameter, to a depth of 1,100 feet, and takes out a core 1$\frac{3}{10}$ inches in diameter. Its price is $2,500. The "B" machine drills a hole, 2 inches in diameter, to a depth of 2,000 feet, and takes out a core of 1$\frac{3}{8}$ inches diameter. Its cost is $3,000. The drills are sold *outright*, without any restrictions. (The agencies are: Chicago, 176 Dearborn street, room 16; Denver, Col., in the Colorado National Bank building; and Ottumwa, Iowa, corner of Main and Market streets.

The handsome Mexican Pavilion stands about 300 meters or yards east by north from here. It is of Moorish design, reminding one of the Pavilion which Mr. Furness built for the Brazilian Commission in the main building of the Centennial Exhibition, except that the Mexican structure is very much smaller, and stands out in the open air, apart from any other edifice. It is surmounted by a dome of glass, which in its turn supports an eagle.

South of the southern extremities of the machinery annexes, and between them and Horticultural Hall, are the frames for the fireworks. The " World's Tea, Coffee and Lunch Stand," too, ought not to be passed by in silence; for, if it be a very small booth, it enjoys a large name. I copy a part of its bill of fare, posted conspicuously on the ouside:

Ham sandwich	10	cents.
Corn beef, cheese, cake, tea, coffee, and milk	10	"
Chocolate, pork and beans	15	"
Bread and butter, eggs and celery	10	"

"WELCOME."

The façade of the main building is of a pale pink, with brown facings, and all of wood. On entering the building by the middle door, on the south, one observes on either hand a medallion of sheet metal, colored green and set in a rim of reddish brown wood. They appear to represent coats of arms, but their identity could not be made out, and the guardian of the public peace on duty in that neighborhood resented somewhat scornfully the imputation that he should know to what they referred.

On entering the main building by this door one is dazed, as usual in large fairs, by the enormous extent of the covered show, and does not know whether to go to the left, right or straight ahead. Among the first objects to rivet the attention at this point is the fanciful dragon on the Chinese exhibit. This monster is made of sheet metal, and colored in that terrifying manner which only the Chinese understand.

The record of observations must necessarily be desultory, since the objects themselves are placed on the floor with very little regard to system, so far as the writer could discover. It is true that several things of the same kind are sometimes found near to each other, but the reverse is more frequently the case. Among the most interesting of all the collections witnessed by the writer, is the Japanese Educational exhibit, near pillar NN—10. The merit of the exhibit deserves all the more praise from the fact that the invitation of the General Government, and especially of the Interior Department, to participate in this Exposition, was only received by the Japanese last August. No more than the briefest sketch can here be given of it, though it is one of the most instructive in the whole Exposition. It is well divided, and systematized too, as follows: 1. Children's toys, with bows and arrows for boys; and battledores and shuttlecocks, hand-balls and kitchen utensils for girls. 2. I-ro-ha-tato-hi-karuta (alphabet cards); "Syllabary" cards for the purpose indicated in their name and also for inculcating moral maxims; Natural History cards to play Japanese checkers with, and at the same time to learn the names of animals and other objects. 3. Sugoroka, a kind of Japanese backgammon (the varieties exhibited principally for girls, and designed to acquaint them with women celebrated for virtue, and also to instruct girls in the mystery of silk making). All these and many other similar objects are classed under the general head of "Kindergarten apparatus, and not with the following, which are more properly of use in the more advanced curriculums for educating the young:

A. The regulations of the Kindergarten attached to the Tokio Female Normal School.

B. Kindergarten toys, pictures; Kindergarten gifts; ruled blackboards; moral story charts; book on Kindergarten games, etc.

C. Work of the infants in the Kindergartens: Pea and straw work, etc.

Elementary Schools:

A. Photographs, ground plans, etc., of various schools.

B. Regulations of school management, etc.

C. School furniture and apparatus, desks, chairs, drawing instruments, blackboards, ink-boxes, luncheon-boxes, chop sticks, instruments for collecting and preserving insects, paper slates, paper blackboards, chalk, and water-writing copy books. These latter are sufficiently ingenious to merit a few words. They were invented by Mr. Ikeda Jetsutaro and their peculiarity is that the characters are traced by a brush with water instead of ink. The writing remains long enough for the master to correct it, and then disappears entirely leaving the paper fit to use again. It is a sure preventive of the usual condition of boys' hands and faces; though the natural talent of the average small boy to get dirty would doubtless not be seriously hampered by the shutting off from him of this means.

D. Elementary school apparatus, geometrical models, models of clocks, abaccus, etc., minerals, astronomical models, geographical model. The physical apparatus is very ingenious and noteworthy. It has been manufactured by Kiôikuhin Seizô Gaisha (a private company in Tokio). It is made almost exclusively of bamboo, and where such flexibility is required as the reed itself does not afford, a number of small pieces of bamboo are attached together by small sections of gum tubing, the whole making a system which appears to fulfil all the requirements of connecting air passages for air-pumps, etc. The greater number of the pieces of apparatus shown, were made by the students of the Tokio normal school, under the direction of their instructors, who thus provided them with the best possible manual practice, and at the same time an invaluable experience of the various physical agents under a variety of circumstances.

E. Educational works for school use. Among the various text-books, native and translated from foreign sources, one notices Roscoe's Elementary Chemistry and Cooley's Easy Experiments in Physics. There is also the Hokkai Shobunten (or grammar of the languages used by the inhabitants of the Yezo), concerning which we are told that these inhabitants are ignorant of letters, and speak a language peculiar to themselves. Hakodate-ken therefore arranged the two languages (it is to be supposed of the other parts of Japan and of Yezo) side by side, in order that those who were ignorant of letters might read the differences between their native tongue and that of the polished Yeddoan.

F. This division is taken up with the work of school pupils.

G. This is devoted to tables showing the standing, etc., the physical growth and development, the weekly record of the elementary school attached to the Tokio normal school, and the specimen register of the pupils of the same school.

Similar categories are given of the secondary schools, the higher female schools, the "schools of female handiwork," and gymnastics. In this latter exhibit there is one series of views representing the game of "Dakiu" played by schoolboys on foot, which bore such a distinct resemblance to "Shinny," that the eye of everyone who had ever been a real American boy, sought it out with wonder and delight. The same game played by a set of tea-caddy figures on horseback gave an idea of the violence with which the Japanese enter upon sport, and bore an even greater resemblance to "Polo." Next came the professional schools illustrated by photographs, models, maps, their regulations, the work done by their students, and calendars and descriptions. After this came the higher education represented largely by exhibits illustrating the University of Tokio. With these exhibits was a mannikin made up of 100 pieces doweled together by small iron wires or rods, hooks, etc. Following these is a class showing the books and publications relating to the subject. Then comes an exhibit of musical instruments both Japanese and Chinese, and European. The last subject presented is that of reference books for those engaged in education, and the regulations of the Government regarding the whole subject. The whole exhibit is most creditable to the little nation sending it, and teaches us again that we have much to learn from our oriental cousins, even in those things which, at the same time, we are teaching them.

The exhibit which is sure to attract the most attention, and which has, perhaps, the merit of the greatest care and expenditure, and much more than the average taste and even classification, is that of Mexico. On entering the building by the middle door of the eastern side one sees at once the brilliant green, white, and red flags of Mexico intertwined over the whole of the area occupied by our sister republic, so that there is absolutely no difficulty in following the aisles from north to south, though it must be confessed that a very little additional care would have been blessed by every visitor who had a more serious object in viewing the collections than passing away his time. The lack of proper regard to any natural system of classification renders study unnecessarily difficult. The show-cases used are very similar to those employed by Germany at the Philadelphia Centennial. They are black, with a very slight relief of grooving and gilding to lift them out of the suspicion of having once formed part of an undertaker's establishment. It may occur to the uninformed, too, that it is odd to see great trunks and slabs of trees equally with pyramids of sugar and bags of coffee locked up in these hermetically sealed cases; but in reality it is done in order to avoid any suspicion of violating the Revenue laws of the United States, it being known even down in Mexico in what horror we hold this particular sin. So that the light-fingered gentry may as well at once abandon all idea of secreting under their coats any of the 500 kilogram slabs of mahogany, etc. This pre-vision on the part of the authorities, and loyalty on the part of our neighbors, must have the effect of discouraging them.

Señor Eduardo Kuhn seems responsible for most of the exhibits of hard woods, and furniture made from them; and these articles form a very notable fraction of the Mexican display and are highly creditable both to the good taste and to the enterprise of the commission. There is, first of all, a large column of polished woods of Mexico (not in cases), and several special exhibits of ornamental carving, which are very beautiful. Among these latter may be particularly mentioned some ornamented, carved, picture frames, an inlaid table and a secretary, which resemble some of the masterpieces of Italian workmanship. Besides the foregoing, were various articles of dark wood furniture all bearing the name of Señor Eduardo Kuhn. Another exhibit (the first to strike the eye of the visitor entering the enclosure from the south, is the chocolate manufactory of the City of Mexico. It is thus explained to the observer:

"The Tabasco Flower. It is the leading and most favored fabric of chocolate in the Mexican Republic. First it made use of steam engine for the manufacture and was introducing in Mexico all improved machinery of the modern system. It has got the highest rewards in all Mexican and foreign exhibitions where his produces have been sent. At none in Mexico has been awarded so numerous premiums, of which there are the centennial medal of Philadelphia, and 14 golden medals. Ignacio K. Ferrer. City of Mexico."

Of course one expects to find the most beautiful Serapes, or Mexican blankets, in this exhibit; and one is not disappointed. There are some of these in the cases at one extremity of the space which for fine workmanship and beauty of coloring exceed any specimens of the kind which one would be likely to find in the whole extent of our sister republic. But the horsemen's hats, with their silver and gold embroidered tassels, and their very ugly shapes, are not more elaborate than one can see in use in any of the larger cities of Mexico. Besides, they always are open to the suspicion of having been made by machinery in New England. The figures, which are usually ascribed to the Indians, are disappointing, *i. e.*, they are neither better nor worse than those which one finds everywhere in the shops of Mexico. Much more instructive is the display of the products of the various manufactures founded upon the Maguey plant (often called the American Aloe). Bags, hammocks, bull ropes, and harness are shown, which have been made of the "Pita" and Maguey. The whole display is highly creditable to the Mexicans, and although not very large compared to the resources of that growing State, and the facilities for sending its products to New Orleans, it is more comprehensive, better chosen, and better arranged than any single exhibit, or group of exhibits, in the United States space.

Among the few articles included in what, by a stretch of the imagination, might be called the British Department are, first, Henry Mann, Son & Co.'s Nonpareil Velveteen Works. The cloth is cut by a woman who explains the peculiar knife and mode of using it. The cloth is cut in "the gray state," and is colored afterwards. Another exhibit which, if not important, is at least not devoid of a certain attractiveness, is found also in the English department, viz., articles of slag for the table and mantelpiece, which is made to imitate the veining of marble, and agate. The articles are not as cheap as one might suppose they would be from their origin, but as a means of utilizing blast furnace slag (and other kinds), they illustrate a new industry which cannot be entirely neglected in even the most superficial view of the exposition.

The Chinese exhibit is to a large extent the counterpart of what it was at the Philadelphia Centennial, but has some new and admirable features. One of these consists in a series of life-size figures with very diverse facial expressions, representing the costumes and employments of the inhabitants of the Flowery Kingdom. Amongst the rest are figures representing the collecting, preparing and weaving of cotton; the costume of a Buddhist priest, etc. All these figures were exceedingly artistically arranged and draped, and as different as possible from the horrors representing the artistic taste of this, the most favored Christian nation, of which some will recall the "Signers of the Declaration of Independence" during the exposition of 1876, and all can see examples among the exhibits of some of the Government departments, which will be mentioned presently. It does seem to the observing layman as if there must be something in the arrangement of figures to look like human beings, which menaces the liberties of the "Great and Free people" which we are apt to call ourselves. It is only on this ground that much of the art at Washington, and all of the lay figure productions of the Government can be accounted for.

One of the exhibits which ought to be well illustrated, and in fact does take up a great deal of room, is the industry of ice-making. Two or three machines (all more or less improved forms of the old Carré machine) are found (singular as it may seem) together, close by one of the walls of the main building. One of these is the machine of H. D. Stratton & Co., of Columbus, Ga. The machine has a capacity of 5 tons per 24 hours, and is said by the exhibitor to produce ice 14×14 inches square and 33 inches in length (representing a block weighing 200 pounds). In connection with this machine are two storage rooms, 12×12×9 feet, for preserving meat, fruit, etc. The machine depends, as do all the machines of its class, upon the absorption of heat in the conversion of liquid to gaseous ammonia, and the removal of this heat by outside cooling. The heat is thus extracted from a large tank of salt water, which acts as a reservoir of "cold!" The cans containing the water out of which it is intended to make the ice, are plunged into this tank and their contents, when frozen, come directly to market. So far the Stratton Co. only bases its claim to more patronage than its neighbors on the grounds of "simplicity, economy of fuel, durability, accessibility" (of the several parts of the apparatus), and no one need be astonished if these claims lose nothing of their real merit from modesty in being put; but what must be supposed to be Stratton & Co.'s estimate of the intelligence of the public attending the "World's Centennial and Cotton Exposition," when it proceeds to claim, under the caption of "The quality of ice produced . . . and the next valuable point is the *durability* of the ice produced. We freeze ice at a temperature of about 5 degrees Fahrenheit—that is, the ice is cooled 27 degrees below the freezing point, which ice *contains fully 20 per cent. more cooling capacity than ice at 32 degrees;* and being so thick, namely 14 inches square, it will *last much longer* than the best Northern ice." Doubtless there may be some persons who will visit the New Orleans fair who will be taken in by this statement as certain persons were, some years ago, by the reported discovery in Mount McClellan of a mass of "permanent ice," which was so powerfully cold that a small piece of it could be used to cool large quantities of water without perceptible diminution of its substance or increase of its own temperature. Such persons will, however, be rarer than means of conveyance, here if such an hyperbolical comparison may be allowed.

Several forms of fire-escape were exhibited, none of which were remarkable for their apparent applicability, simplicity or cheapness; but an experiment with one of them in the Exposition added two transient patients to the hospital, and very nearly added to the occupants of the above-ground mortuary temples of the Crescent City. One with which no accident occurred, was sent by Seagrave & Fuller, of Worcester, Mass. It consists of a boatswain's chair on a pulley, the latter being easily controlled by a spring catch, etc.; but the question of how to get down from a third-story window when the second story is in flames, and one has not this very comfortable apparatus already rigged, seems as far from solution by this invention as ever.

One of the labor-saving machines contributed by New Orleans itself was the "wonderful combination self-heating iron," of Mrs. Fox. This was exhibited by its gifted inventor near pillar D-46. It consists of a hollow case shaped like a flat-iron, which is capable of rotation around the handle. A gas tube is attached to the axis which forms part of the handle, which latter is perforated to allow a number of small jets of flame to burn in the hollow body of the iron; so that while one surface is being used, another is being heated for future use. Mrs. Fox believes that ironing thus becomes a pleasant pastime. (We are somewhat incredulous about this.)

There are several type-writers exhibited near each other which introduce new features into the art. All of them are from New York and its vicinity. One is the "Columbia Type-writer," (office at 320 Broadway, New York city). This is a convenient little apparatus which has the advantages of lightness, cheapness, and adaptability to various purposes, but not speed and ease in writing. It costs complete, $25. Another form costs the same as the Remington, but can employ different fonts of type, which can be changed at short notice, and has a larger number of characters, which are operated by a piano key-board. On the other hand, the paper must roll up in an enclosed cylinder, and, the movement of the type being in a horizontal plane, no alterations of alignment to suit specific purposes is possible.

The American wines are fairly represented, including the Jarvis Brandy Co., of California, and the Cook St. Louis champagnes.

Henry Bornstein, of 7 Lancaster st., Boston, has not hesitated to bring to the notice of the international public his patent pin hooks for tidies and pillow-shams.

Germany is represented by one of the countless "genuine Farina Cologne" collections, which have by this time been tolerably well impressed upon the attention of the world.

The Meriden Britannia Co., of Meriden, Conn., has a fair display of its electro-gold- and silver-plate. This is so familiar to the public that it needs no "bush."

Jesse Marden, of 55 S. St. Charles st., Baltimore, has a very good exhibit of scales and balances for all sorts of purposes, and sets of metric weights of convenient form for handling.

The Chalmette Mills exhibit, near TT-12, a cotton bale and the product of their manufacture in sheeting. Close by (TT-7), an excellent collection of specimen ornaments, figures and columns is shown by Bakewell & Miller.

At one extremity of the Mexican exhibit, but forming no part of it, is a somewhat uneven exhibit of Mexican goods by a Mr. Peters (an American), who has brought the articles through the United States Custom House, and has them for sale. Many of these goods have been chosen with excellent judgment and are not dear compared to other things in the Louisiana metropolis. The feather pictures are very pretty, and indeed show a delicate appreciation of the requirements of true art on the part of the Mexicans by whom they were made.

Cooper, Hewitt & Co., near pillar E-15, show a small collection of articles, many of which were old friends first seen in the Centennial, NOT of cotton. In addition, there is a specimen of "corrugated strip iron for fences." This firm has the contract for the iron work of the projected Brooklyn Elevated Railway, and is turning it out at the rate of 60 tons per day.

The Pratt & Whitney machine gun is an interesting addition to warfare. It fires 500 shots a minute from two stationary rifled steel barrels in a water jacket, which prevents undue heating.

At E-28, the Thomson-Houston Electric Light Co. makes a very good display of its light. Close by is an Edison Pavilion which presents samples of all the kinds of electrical apparatus which that electrical genius has invented.

The machinery of the main building and that portion which has the distinctive appellation of Machinery Hall, is driven by two engines located nearly in the centre of the large building. Each engine keeps in motion the shafting on one side of the building. One of these is a Reynolds-Corliss engine, and the other a Harris-Corliss, of Providence, R. I. A 28-inch Gandy patent belt keeps the shafting in uniform motion with the large fly wheels. The power is transmitted regularly and easily but not so noiselessly as was the case with the monster Corliss of the Exhibition of 1876.

A very handsome display is made by the Northwestern Terra Cotta Works of True, Brinkhorst & Co., of Chicago. This included tablets, pillars, bas-reliefs, etc., all of which showed good workmanship and design. Near UU-37, the Monument Bronze Co., of Bridgeport, Conn., has a good exhibit of "white bronze" monuments in every way creditable to it.

The Birdsall Portable Saw-mill, at MM-59, illustrates an admirable adjustment of the necessities of this kind of industry to the needs of the ever-moving lumbermen. In this connection, too, should be mentioned the excellent adjustment to variable feed and perfect and easy control of the circular saw-mill of Liddell & Co., of Charlotte, N. C. and New Orleans, La. There is not space here to describe the mechanism, but it may be said that by the slightest movement of a lever the velocity of the feed is controlled or reversed, according to the will of the engineer.

The McCormick Reaper and Twine Binder holds the place which it has always held in spite of the active competition of both American and foreign inventors. It will be remembered by many interested in this branch of industry what a surprise was given to the Americans during the Centennial Exposition by the exhibit of the Russian agricultural machinery. But the old McCormick Reaper and Binder has never yet been surpassed, and it is somewhat questionable if, for the purposes to which it is adapted, it ever will be. (II-56.)

Not far from the reaper is the Curtis Improved Factory Churn, which, if it does not astound us with any novelty of principle, serves to remind the casual observer to what enormous proportions the dairy industries of the United States have grown.

The wagon building, mentioned in the early part of this sketch, contains fine specimens of the wagon-builder's art from all over the United States, but nothing especially novel. Indeed the remark made elsewhere about meeting old friends of the show of 1876, applies perhaps more than in the main building. This tendency to build one or more sample objects for the needs of a great fair, and to keep them for use at future fairs, held even ten years afterwards, is not calculated to give the visitor confidence in the representative character of the said samples, nor in the enterprise of the exhibitors. Amongst the gimcracks included in this department is a patent gate so arranged that by pulling a suspended wooden bar the gate rises and shoots into a slot made for it in the post. It is called the "Stong Excelsior Farm Gate," and one of its recommendations is that when the snow lies deep it still will operate. The suggestion of the application of this invention in New Orleans, where the temperature was about 80 degrees, had its humorous side.

Michigan cider was well illustrated at FF-20, where a somewhat enthusiastic person descanted on its merits as a beverage as if there were no such thing as cholera.

The Louisiana silk-spinning exhibit at FF-15, was, or rather would have been interesting, had the manipulation not been subject to frequent interruptions. Nevertheless the heating of the cocoons in boiling water, and the reeling on spools of the rich golden silk were very interesting details to those who had not seen the *modus operandi* previously.

The French section is found near (R-20-24), but it is not at all a fair sample of what that great centre of taste and culture ought to display. A few vases and bronzes such as are found in any jewelry establishment of any city of twenty thousand inhabitants, a few "articles de Paris" are all that attest that "la belle France" is the exhibitor.

The Austrian exhibit is not very different. There are some quite comfortable looking bent-wood chairs and stools, and apparently numerous orders for them; but any such variety of objects and industries as should characterize one of the "Great Powers" is looked for in vain.

The galleries of the main building are very spacious, but seem to be but little visited. Many of the exhibitors there alluded to this fact and complained of it. Several of the exhibits there are among the best and most characteristic of the entire show.

At V-16 is a display of stained glass which is not very remarkable. At V-18 Mrs. L. E. Beard, of Detroit, exhibits a species of artificial paper flowers which she has devised, and which are extremely pretty, but not the sort of thing for which most people go to a world's fair.

The Leedom carpet works make a creditable showing for Philadelphia on the same gallery, and not far from the last-mentioned exhibit. Hubbard's hammock chairs, well known in the summer resorts of the luxurious, are also at no great distance, but all the exhibitors in this part of the building appear to be suffering a banishment like Arabi Bey, and eagerly scan the features of any new comer, whose footsteps are heard echoing down the broad wooden way. This interest, while it may be mistaken for flattery becomes embarrassing when the stranger is a modest man, and cannot easily tear himself away. The furniture exhibit of Tisch at NN-2, is fair without being of a character to delay the visitor very long.

At D-2 is a collection of medical furniture among which are articles which remind one of the nameless curiosities of Hotel Cluny, in Paris. For instance, Dr. Wilson's "Gynœcological chair," if it had been known to the Spanish statesman in the palmy days of the Inquisition, would have been turned to excellent account in some of the ceremonies which delighted the people of that epoch.

Following Dr. Wilson are many kinds of carriages and furniture along the broad passage until one arrives at the "Daisy automatic light swing maker for children" (FF-62). But without doubt a really unique, as well as the finest exhibit in the galleries is that of Mr. N. Friederich, of San Antonio, Texas, who has for some years enjoyed a national reputation for his beautiful cattle horn furniture. After comparing Mr. Friederich's work with the best European manufacture of like objects, it must be said to Mr. Friederich's credit, that nowhere can one find these expensive luxuries finished with a more conscientious regard to their durability, and with more good taste, than in his specimens. The horns which he weaves together to form the backs and arms of his chairs, are all first carefully cleaned inside and filled with plaster of Paris in their narrow and tortuous parts, while the straighter and larger parts are filled with pieces of wood carefully cut to fit them. Thus if one of these handsomely prepared horns falls on the floor it is not injured. Chicago, at UU-58, presents a bar counter and sideboard under the title of "standard saloon fixtures," which confirms the often expressed view that she is the champion of the world in all that concerns this sort of public conviviality.

It seems almost unavoidable to express surprise that many obvious lessons as to the means of providing for the health and comfort of the public which might have been learned at the Philadelphia Centennial or any other of the great world's fairs, appear to have been entirely unlearned; and the management of this one seems to have approached the problem as if there were no experience to guide one, and that all the facts had to be established for the first time by the experience of the New Orleans management. This has been a great and costly error, and moreover it has prejudiced the success of the fair from the start.

The S. S. White Dental Mfg. Co. of Philadelphia, makes certain articles for the whole world, has exceeded all its previous efforts in the display of novelties by an act which cannot but be regretted. In the last decade or more of political corruption we have not been surprised to hear mutterings from the public men who felt their own insignificance beside the greatest of patriots and soldiers. We have seen it slyly inserted into the newspaper paragraph that Washington was sharp at a horse trade; that he would occasionally indulge in profanity; that he was a sham in fact, and only presented his fair side to the world, etc. We have always indignantly repudiated this idea, and demanded an instance of his hypocrisy. Now, the S. S. White Co. comes to this World's fair with a set of false teeth, each one of which was carved out separately from a piece of ivory, and tells the world that this is the machinery that the great George employed to masticate his elegant Mount Vernon dinners. Such conduct merits that the rest of the exhibit of this firm (which is really very fine) should be passed over in silence.

One more Chicago exhibit should be alluded to since it is characteristic of the enterprise, dash and appreciation of the value of time of that great metropolis. Herr N. Neufeld of 25 Randolph street (that city) paints oil pictures for the public "while you wait." It is said by some of his fellow-citizens that his talent is really as great as that of Meissonnier, but that it requires a brainy, progressive place like Chicago to do it justice. While the crowd waits, a canvas grows from gray to white, and from white to blue; and rapidly the natural tints of a landscape by moonlight or sunlight start out as in the stereopticon, and a new symphony is born. Price $1 to $1.50, according to size.

THE UNITED STATES BUILDING.

This is a building much smaller than the main building and dedicated to the exhibits of the United States and the several States. Here may be seen a healthy rivalry among the latter and the results of the experience, taste and leisure of the officials of the Government Departments at Washington. Of course the Smithsonian cannot fail to outshine the other branches and twigs of officialdom in a line so completely its own; and accordingly one sees a fair proportion of its collections well labeled, arranged and displayed. Among the objects most generally interesting to the public are its display of casts, breeding apparatus, etc., of the food fishes.

Most of the Executive Departments of the Government (if not all) are represented with some approach to regardlessness, but not always (it must be confessed) with good taste. For instance, the Interior Department leads the van of the teratological procession by a display of a monster latticed Easter egg designed (so far as the average visitor can see) solely to illustrate how much money can be spent without any apparent purpose. This thing looks like a patched-up ostrich egg, with views of Swiss scenery or geography painted over it at a Kindergarten. Its form is a prolate ellipsoid and its longer diameter is vertical. Perhaps it is the globe amended by the Interior Department, (a notable improvement on Nature.)

If the Interior Department has won the prize for the solution of the problem of how to put money where it will do the least good, the Post Office Department is not far behind it with an object lesson-panorama resembling those which adorn the outside tent walls of the parasitic side shows of Barnum's Museum. This extraordinary production stretches around three sides of a square at a distance of some ten feet above the heads of the visitors, and represents: 1. A row of dwelling houses. 2. A few factories. 3. A double-decked bridge supposed by the public to be either the Eads bridge, the Brooklyn bridge, the Pons Assinorum, or perhaps a Venetian structure (as it is evidently a bridge of size). A stage coach, a train of cars, a pony and rider, and various other things either are about to cross, are crossing, or just have crossed the structure, which shows that it was not put up by contract of the Post Office Department. Opposite to the dwelling houses and factories and on the other side of the river are plains, bad lands, mountains, valleys, and all the things that may be supposed to arise on the night-mare imagination of the Ring, after a Star Route dinner. Talking of that, a very neat and appropriate idea of the Post Office Department is the exhibition of the officials of the various Post Offices grouped together in *star-shaped* frames, with the Postmaster of the place in the middle, and his genial staff occupying the points of the star. This idea deserves to be perpetuated in the seal of the Department.

The Navy Department has to a large extent the same objects which were shown at the International Electrical Exhibit, including the same jolly Jack Tar to explain them. His cold-blooded indifference to peril, while explaining the action of the terrible torpedoes, to nurses and children, fairly makes the flesh creep.

The Greely Relief Expedition is displayed not far off, presumably by the War Department. The figures consists of suits of furs occupying very exactly the attitudes given by Thomas Nast to his pictures of the rag baby, but into the hood of each suit has been thrust a hair dresser's dummy (usually nearly right side up) making the entire figure look like a new thing in "grab bags," or a Laplander's Christmas stocking. They are beautiful, and a great deal more artistic than most straight jackets.

The various States seem to have vied with each other in presenting their several exhibits in a manner agreeable to the eye.

Pennsylvania cannot, however, be justly included in this statement; for although it may be true that the gentlemen who have endeavored to secure a collection of her products, and a general resumé of her industries, have not been sufficiently supported by the State Government or the people; the fact is nevertheless patent that the exhibit in her enclosure is chiefly notable for what it does not contain. The State displays are contained in areas either railed around on the open floor, or ranged around the walls with partitions to separate them from each other. Pennsylvania belongs to this latter class. The first and most prominent object to rivet the attention on entering the miniature domain of the Keystone State is a very large, life-size oil painting of Zachary Taylor. No doubt the commissioners had some reason for putting this picture there, but unfortunately the gentleman in charge of the enclosure at the time of my visit could not inform me of it. He said, however, that the painting was valued at $10,000 at that time. What it may be worth now, is somewhat difficult to say owing to the fact that the lower part of the painting seemed to be exposed to the direct rays of the semi-tropical sun of that latitude for the greater part of the day. Large photographs of several of the officials of the State Government, the Philadelphia Government, etc., occupy a proportionately larger amount of the space of the State than any other industry. But here, too, the classification is not quite fair; inasmuch as the arrangement robs Scotland of part of the glory that belongs to her, by placing Mayor Smith among the Pennsylvanians. Governor Pattison, Simon Cameron, General Hartranft and Senator Wallace are comprised in this family album, and the superficial observer would imagine that this was the most valuable as well as the only unique kind of production that the State could show; much more so for instance, than the petroleum trade, which is presented to the world in a couple of long thin bottles containing liquids of various shades of brown. The Alabamian, or Louisianian who, misled by the glowing account of the superiority of the resources of the former State to those of Pennsylvania, which a distinguished Philadelphia editor has recently given, and wishing to learn something of an industry that was forgotten when those flowing periods were written; would be obliged to assume that the oil was obtained from brooks or rivers, or from the rain cistern, so far as the exhibit professing to illustrate this activity instructs him. The iron works of the State are easily accomodated on a table space which would be deemed insufficient for his daily needs by many a country lawyer. The volumes of the "Second Geological Survey of Pennsylvania" were indeed found arranged in a dusty row on an out-of-the-way stand, but there was no large map such as many of the other States prepared, to give the non-Pennsylvanian an idea of the relative positions of the various mineral fields of the State. The The day of one visit to this shrine was said to be "Pennsylvania day" but no one was observed about the place whether visitor or attendant. (It ought in fairness to be said that this refers to the *evening* about 4.30 P. M.)

Ohio makes a very fair show.

California is seen from afar by means of an American flag of nearly twelve by six feet made of pampas plumes. Sonoma County also has a very handsome semi-circle of pampas plumes twenty by ten feet.

Arizona may be given credit for a very good display of copper and silver minerals, and for her cactuses from Cactus County. Among the pleasing photographic representations of her wealth of resources, a prominent one is a photograph representing a gentleman hanging by the neck from a telegraph pole, surrounded by a very respectable crowd of citizens, most of whom have put on a holiday expression as if the photographer had just said "Now look as pleasant as you can." The incident took place (so says the legend underneath) on March 28, 1884.

A mineral collection from Cochise County; cotton from Maricopa

County. Potatoes with "no irrigation," copper, lead and silver ores from the Hackberry district, with a handsomely arranged cabinet of minerals belonging to Professor Wore, of Tucson, complete a display which is deserving of attention and redounds to the credit of the enterprising citizens of the State.

Colorado also has put forward not only a valuable sample of her chief (mining) industries, but also a collection of woods and grasses which form a centre of attraction.

Oregon, Idaho and Montana are well represented.

Kansas, Dakota and Nebraska are all decorated with artistically arranged grasses and contain much of interest. The second of those just named has a large grass plot on which are set up a number of stuffed animals as samples of her game.

Minnesota leans toward realism in a display of unconventional Indian figures and a thin artificial waterfall labeled Minne-ha-ha.

South Carolina shows a fine collection of woods, etc., and an immense pyramid composed of her phosphate deposits.

North Carolina comes to the front with a beautiful grass display in addition to those products which are more usually associated with her soil, such as turpentine and lumber and dipping-sticks. Her cotton exhibit is also good.

Virginia spreads before the gaze of the beholder the regulation "Natural Bridge," over which the Father of his Country is said to have thrown a stone, and without an illustration of which any geography of the State would be incomplete. This time it is a paste-board and canvas picture of the great curiosity upon which, in truth be it said, the artist cannot be congratulated. While this takes up more room than anything else, let it not be supposed that there is nothing else in the Virginia department. The rest of her exhibit is fairly good, if not what one would expect from the Mother of Presidents.

New Jersey displays prominently a wooden soldier with a placard to inform us that of such is the material that took the first prize for discipline and soldierly bearing at the inter-State review at Yorktown. The silver vase commemorative of this achievement is on exhibition alongside of the soldier, and serves to point the moral that if New Jersey cannot produce silver herself; she can at least secure what others have produced. Besides soldiers, we learn by the objects that New Jersey produces magnetite, terra-cotta, fish, glass and wine; just as we learn that Pennsylvania in addition to statesmen, produces "Stratena" which will hold them together in spite of a centrifugal tendency.

The habit of granting to a railway company the space for an exhibit of the products of the region which it drains; a tendency carried to excess in the New Orleans Exhibition, cannot be too emphatically condemned. First, it destroys all classification of the various objects by associating a geographical division (by States etc.), with a purely accidental assemblage of things from different regions selected because the commercial necessities of a railway have caused it to pass over a certain number of States in a certain order. Second, these displays being merely advertisements of the railways, their excellence is more dependent upon the wealth of the companies making them, than of the regions passed over. One of the least of the objections to such displays is that the same region is made to do duty several times for different railways and for the States in which they occur.

Louisiana has a fair display of her specialties and also a fine show of artificial flowers. Amongst other things which show both ingenuity and taste is a series of views so drawn that at a short distance they make a word appear. This is done by emphasizing the appropriate lines on a picture in such a way that the general effect of the scene is not interfered with.

It would not be fair to omit mention of the Liberty Bell which was so properly loaned to the New Orleansians. The stalwart members of the police force who were deputed to guard it, doubtless thought that they and it would be a target for continuous pairs of bright eyes in the centre, and amidst the life of the Exposition. In point of fact, their wives and sweethearts (if such there be) may possess their spirits in peace, for the bell and its attendants are stowed away near a lakelet on the grounds where the busy hum of machinery, and the tramping of feet are seldom heard. The rural sight-seers from the neighboring parishes of Louisiana, it is true, often select this spot to rest themselves from the fatigues of walking, and to take their lunch; but its location is usually deserted. The bell looks very imposing on its specially constructed car, and its guardians deserve credit for their vigilance and good nature, but it is not too much to say that scarcely one per cent. of the visitors to the Exposition are aware of its position, if, indeed, they are of its existence.

Another object in the grounds not heretofore mentioned, is the standpipe which on occasions pours a liberal supply of water over its top and produces a much needed sense of cooling. The art gallery is not mentioned for many reasons here among which is that the sketch is already too long.

It may be said as a kind of supplement, that several of the peculiarities of the City of New Orleans will not escape the notice of even the temporary sojourner when his attention is divided between its ordinary attractions and this show. The facts that all the drainage is through deep gutters on the surface, and that all the "vaults" are structures of marble or other stone for the reception of the dead, built on the surface of the ground, will occur to him as important factors in the prevalence of yellow fever. The streets of the city are indescribably filthy, and malodorous, and the levees near its busy parts reeking with offal. The cistern water, which is used for drinking purposes, is (frequently) as discolored as the Mississippi itself, and can hardly fail to be an active agent of poison in the sickly season. The buildings are, many of them, very large and stately, and the appearance of the city viewed from the summit of the Cotton Exchange is one to impress one with its commercial importance. But many of the houses are unaccountably damp, and in reality almost every stranger during the last month or two has been promptly attacked by an influenza and fever. Some of the customs of the city are peculiar. For example, during the time which has been alluded to in the foregoing notes, there died a M. Armand Pitot, and notices of his death were observed attached to the telegraph poles, and some public buildings throughout the city. It is true that he appears to have been a man of unusual influence and popularity, but this manner of distributing a "faire part" would have been thought strange in France itself. The lake is the great resource of the tired and heated inhabitants during the summer, but it is even in early spring, itself too hot to offer any but a comparative relief. How hot must they be who are relieved by a trip to its shores in summer!

During the Exposition the superb band of sixty odd musicians of the Mexican army played alternately in the main building and at the lake; of which the two resorts, situated about three miles from each other, are Spanish Fort and East Side Park. The former of these was the scene of the concerts. It is strange, but true, that Wagner's music was rendered with an intelligence and expression worthy of Thomas himself.

The squadron of United States vessels lying in the harbor offered almost as much of interest to the visitors as the fair, if one may judge from the crowding of the boats which took off the public to the ships. The naval vessels are better supplied with water than any resident in or near the city, for they use condensed water, not only for drinking purposes, but even for washing the decks.

It was the writer's good fortune to be present at one of the grand drawings of the L. S. L. (or Louisiana State Lottery), The drawing took place in a little theatre near the St. Charles Hotel during the morning hours (and perhaps for a part of the afternoon). Nothing could be fairer than the drawing of numbers from the huge glass drums, and if the calling of the numbers any unfairness exist it must be practised some time anterior to and taking of the little cylindrical boxes which contain them out of the "wheels." The scene was a peculiar one. To the right and left of the stage respectively sat Generals Beauregard and Early. The former a decidedly fine looking and quite Creole-like old gentleman, with white flowing moustache and unmistakably French features. As I looked at him with half closed eyes I thought myself back again to that period twenty-four years ago when the whole people were frenzied at the news from Charleston, the firing on Fort Sumter, and the assumption of active hostilities by General P. G. T. Beauregard who never gave the readers of his proclamations the grace of an omission of one of all his alphabetical fore-names. Then I remembered so well a certain calm evening about February 1, 1863, when a fleet of ten or twelve vessels were lazily rolling in the at-all-times heavy sea-way outside of Charleston Harbor, and while the flag-ship "Powhatan," Commodore Gordon, was in the act of performing its military Angelus, that a small speck was seen coming out from the direction of the city. The Quartermasters soon made her out to be the Rebel Ram "Chicora," accompanied by another craft, and the Commodore without even stopping the music or depending on the other vessels of his fleet, quietly slipped his anchor and went directly towards the approaching enemy with a full head of steam. But the flag-ship had not moved far when it became apparent that the others were retiring. A few minutes more and this was patent to the naked eye, and thus would have ended an incident akin to that of the alleged King of France and his men, had it not been for the imagination of a Beauregard. For, what was the surprise of all the officers and men of the fleet to see a few days afterwards in a Rebel paper the proclamation of the great proclaimer stating that the two vessels aforementioned had run out to sea five miles beyond the usual anchorage of the fleet without having seen a Yankee gunboat. And here was the old gentleman himself sitting before us neatly attired, his body erect, his feet slightly spread apart, and his hands receiving the little boxes from the hand of a lesser than he, opening them, taking out the little slip which each contained, and reading the number thereon inscribed, which he repeated in a low but distinct voice to an attendant who repeated it aloud in the manner of a soothsayer announcing to Cæsar the fate of the Roman legions. The solemnity of this utterance of itself would have dispelled any lingering doubt as to the entire good faith of the whole performance. On the other side sat the small and somewhat bent form of General Early; adorned with a great flowing white beard. But his eyes were sparkling and penetrating, and one recalled many things of him of quite another kind. For instance, there are Philadelphians who were either regular or temporary members of the first Troop of City Cavalry during the emergency campaign of June and July, 1863, (and among them our then Cornet the Hon. Samuel J. Randall), who will recall towards the end of June of that year a certain march made with extraordinary expedition due to an earnest desire on the part of all not to incommode the march of White's Brigade of Cavalry which formed part of Early's Corps. Here was the old Confederate warrior in the flesh, whose bare name caused the lamented Samuel Small, then Chief Burgess of the town of York, to ride miles into the country in order to deliver up the "keys" of the town; and looking just as full of life as ever, in spite of being somewhat bent by his advanced age.

FLUID CIRCULATION OF THE SUN'S MASS.—Father Lamey assumes the fluidity of the solar mass as a fundamental postulate and endeavors to show that in consequence of the continual cooling of the superficial layer the entire mass must be kept in constant circulation. The result may be represented by a veay simple geometric curve having many points of tangency with the surface of the solar globe. He considers that this curve furnishes a satisfactory explanation of the general distribution of sun spots, their double movement in latitude, the eleven years' period of solar activity, the variation of the movements of the spots in latitude, the conservation of solar energy, the inequality in the periods of increase and decrease of superficial activity, the periodical oscillation of the chief zone of sun spots, the inequality in the activity of the two hemispheres, the variations in the velocity of rotation, the inclination of the hydrogen protuberances and the characteristic configuration of the corona.—*Comptes Rendus*, May 6, 1884.

C.

A SIMPLE FORM OF DRAUGHT GAUGE.

BY PROFESSOR J. BURKITT WEBB, of Cornell University.

During the Electrical Exhibition I had the pleasure of devising, and by request now describe, a simple instrument for measuring the vacuum in a flue directly by means of scales, and without using a column of a liquid or a spring. It was used simultaneously with other instruments for the same purpose and gave good results; it is to be recommended for the directness and certainty with which the results are obtained, and the absence of any necessity of standardizing it to get at the true value of its readings.

Any form of scales may be used, weighing, preferably, to fractions of an ounce. Upon the scale pan, *A*, (see Figs. 1 and 2) is placed a board, *B*, in which there is an annular groove filled with mercury; this and the scales are the only moving parts of the apparatus. The rest consists of the lid, *C*, whose edge dips into the mercury in the groove, and the pipe, *D*, which connects this lid with the interior of the flue or stack, so that the same vacuum exists beneath *C* as in the stack. This pipe also serves to support the cover while the mercury joint allows the board to rise and fall with the scales. It is evident, therefore, that the atmosphere will press upon the board everywhere except beneath the cover, where there will be a less pressure, so that if the scales have been balanced for the weight of the board and mercury they will be drawn upward by the suction of the vacuum under the cover. The amount of this is clearly equal to the area beneath *C* multiplied by the number of pounds per square inch difference between the vacuum and the atmospheric pressure, and can be obtained directly from the scales and the difference of pressure calculated.

In the pipe, *D*, there is a diaphragm, *d*, through which there is a small hole; this prevents rapid fluctuations from disturbing the balance, while it allows the same average vacuum beneath *C* as in the stack, there being no leakage past the mercury joint. It serves a further purpose, also, in connection with the plug *c*; by withdrawing this plug the atmosphere has access beneath *C*, so that the scales can be balanced at any time without the vacuum in the flue affecting them. The edge or rim of *C* should be thin, and not soluble in mercury; it can be made of sheet-iron riveted and the joint made air-tight by varnish. The area of *C* can be calculated from measurements of its diameter, or by impressing its edge upon any soft surface it can be obtained with a planimeter.

The mercury should be pure enough not to clog the motion, and its buoyant effect upon the cover, whose edge will necessarily be of some thickness, can be utilized to make the scales weigh to small fractions of an ounce, provided only that the knife edges be in good order. To accomplish this, a pointer, *b*, is fastened to the scale-beam so that it will play over a roughly-graduated arc upon the card, *a*, and indicate the exact position of the beam; to find the value of the divisions in parts of an ounce, remove *c* and note how many divisions the pointer moves over when the pee is moved a quarter or half ounce; the thicker the rim of *C* the greater will, of course, be the value of each division. This pointer and scale also allows small changes in the vacuum to be noted without moving the pee.

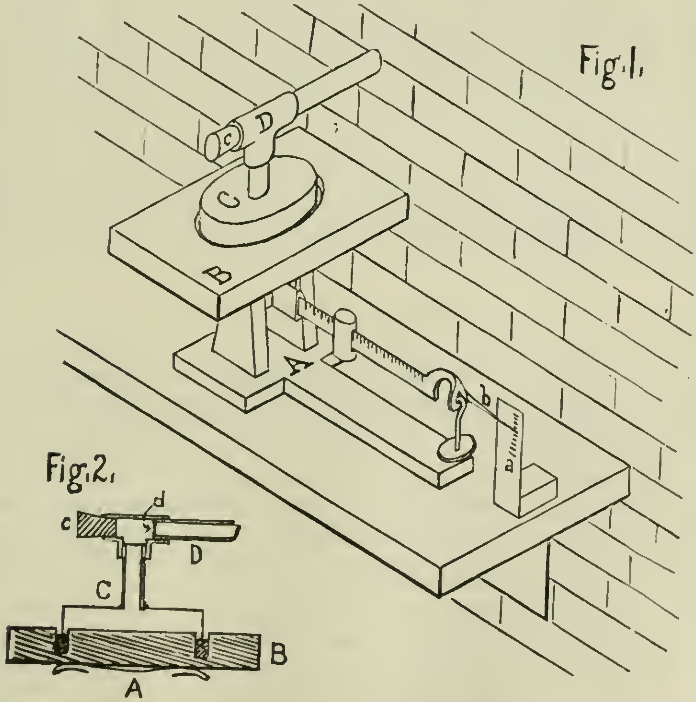
Fig. 1.
Fig. 2.

A modification of the apparatus, which dispenses with the use of mercury, consists in using a shallow metal cylinder in place of *B*, and a flat disc in place of *C*, acting as a piston, the latter being a thousandth or two smaller than the cylinder, so as to move freely in it and yet allow no appreciable amount of air to pass by it. In this form of instrument the diaphragm, *d*, must be replaced by a cock, which can be shut to balance the scales, and has when open sufficient passageway to prevent what little air passes the piston from affecting the vacuum under it to any appreciable extent. The piston must also be hung from *D* by a rubber tube so that it can hang freely in, and without pressing against, the cylinder.

Suppose, now, the cover to have an area of 50 square inches, and the scales to read as follows:

With stopper out	28·50 oz.
With stopper in	20·25 oz.
Difference	8·25 oz.

Dividing by 50 we have 8·25 ÷ 50 = ·165 oz. as the pressure per square inch of the vacuum below the atmosphere; to express this in inches of water divide by the weight of a cubic inch = 1,000 ounces ÷ 1728 = ·58 ounce. Dividing ·165 by ·58 we get ·286 inches of water.

The gauge may be set up at any distance from the stack and connected by a pipe or hose, and as it is equally applicable for slight pressures above atmospheric, it may also be used for determining the pressure of a blast.

COMETARY INDICATION OF COSMIC CURRENTS.—M. Chapel called the attention of the French Academy to the coincidence of the singular transformations in the nucleus of the Pons-Brooks comet with its passage through the region in space where the cosmical currents of the November and December meteors are mingled. He cites, as instances which he considers somewhat analogous, the appearance of a tuft on Cheseaux's comet, January 25, 1744, the new tail of Halley's comet in 1835, at the moment when it crossed the orbit of Biela's comet, and the rupture of Biela's comet on December 19, 1845, two days after it crossed the orbit of Halley's comet. Hence he concludes that the sudden modifications of cometary nuclei and tails are due to the encounter of cosmic materials which the comets scatter over their orbits. This hypothesis accords with the most rational idea that we can form of the resisting medium by which astronomers have sought to account for the acceleration of Encke's and other comets. It may, perhaps, aid us in sounding the planetary spaces and discovering the presence and mode of distribution of cosmic matter.—*Comptes Rendus*, March 3, 1884. C.

ON THE ELECTRO MOTIVE ACTION OF ILLUMINATED SELENIUM, DISCOVERED BY MR. FRITTS, OF NEW YORK.

BY DR. WERNER SIEMENS.

Read before the Berlin Academy of Sciences, February 12, 1885.

Mr. Charles E. Fritts, of New York, sent me, early last year, a description of his method in relation to light-sensitive selenium plates, differing from mine in essential features, and accompanied the same by a number of the plates prepared by him. These do not, like mine,* consist of parallel platinum wires embedded in a thin body of selenium, but of a thin homogeneous sheet of selenium, which is spread upon a metal plate and, after a subsequent heating—for the conversion of the amorphous into crystalline selenium,—is covered over with a fine gold leaf. Mr. Fritts has found that the green light penetrating through the gold leaf, by the further passage through the selenium, increases its electrical conductivity. In fact, the conductivity of the selenium plate between the gold leaf and the metallic base-plate is, by the illumination of the gold leaf with direct sunlight falling perpendicularly upon it, increased to the extent, in some of the specimens sent over, of from 20 to 200 times! The effect of illumination by diffused daylight is also greater in Mr. Fritts's constructions than in mine.

One of the plates sent over to me exhibited absolutely no sensitiveness to light, but in place of that it has another most remarkable property, namely, that a galvanometer connected up between the gold leaf and the base-plate shows the existence of an electric current in the direction of the light-action through the selenium, as long as the gold leaf is illuminated. I, in the beginning, conjectured that this current was not lasting, but had the character of a polarization current, which continued only until the molecular modification of the selenium by the light was completed, and a first trial seemed to corroborate this idea. But further experiments convinced me that this supposition was erroneous. In reality, we have here an entirely new physical phenomenon to deal with, which is scientifically of the most far-reaching importance ("*die von grösster wissenschaftlicher Tragweite ist!*")

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* *Monatsbericht der Berl. Akad. d. W. vom* 13 *Mai*, 1875, *und* 7 *Juni*, 1877.

My experiments have shown that, by the illumination of the gold leaf, a difference of potential is established between it and the base-plate, which is, to all appearance, proportional to the intensity of the light, and which stands forth unchanged so long as the illumination remains constant. Obscure heat radiations do not produce electromotive force, and therefore the supposition of a thermo-electric action, as the explanation of the phenomenon, is excluded. Mr. Fritts holds that the light waves penetrating into the selenium are transformed directly into electrical current, and therefrom states the fact that the strength of the current is proportional to the strength of the light. They showed themselves to be approximately so, by the collated experiments in the following table:

Strength of the light in standard candles..	6·4	9·9	12·8	16·8
Strength of the current..................................	18·	30·	40·	48·
Quotient........	2·8	3·	3·1	2·8

The strength of the light was measured with a Bunsen's photometer, that of the current by the deflections of a sensitive mirror-galvanometer.

With the gold leaf exposed to the light from the southeastern portion of a cloudless sky, while the sun itself was hidden by neighboring high buildings, the series of measurements in the following table were obtained :

Hour of exposure..	9 h. 37 m.	10 h. 5 m.	10 h. 30 m.	11 h.	11 h. 35 m.	12 h.	12 h. 30 m.	1 h.
Deflection of the galvanometer......	190	196	209	223	250	250	244	245

Hour of exposure..	1 h. 30 m.	2 h.	2 h. 30 m.	3 h.	3 h. 30 m.	4 h.
Deflection of the galvanometer	249	228	188	173	172	108

It is shown from the foregoing, that the electro motive force of the selenium plate very uniformly increased from 9.30 A. M. until 11.35 A. M., then, the current remained nearly constant during two hours, and thereafter again quite uniformly decreased until 3 P. M. With regard to the reason why some of his selenium plates become more conductive during illumination, while others generate electromotive force, Mr. Fritts gives no explanation. He speaks of the uncertainty in the preparation of the plates, of whose properties nothing can be foreseen, and gives various manipulations through which unserviceable plates may often be made useful. There is also still needed thorough investigation in order to determine upon what the electro-motive light-action of many selenium plates depends. Nevertheless, the existence already of even a single selenium plate having the property described is a fact of the greatest scientific significance, since there is here presented to us, for the first time, the direct conversion of the energy of light into electrical energy. ("*eine Thatsache von grösster wissenschaftlicher Bedeutung, da uns hier zum ersten Male die directe Umwandlung der Energie des Lichtes in elektrische Energie entgegentritt.*")

NOTE.—The uncertainties mentioned by Dr. Siemens, as existing at the time I wrote the communication referred to (in February, 1884), have since been largely overcome. I have discovered the conditions upon which the electromotive light-action depends, and, with more perfect means for constructing the plates, I believe that I can even now accomplish the conversion of the greater portion of the energy of light into electrical energy. If my theory of the action proves to be complete, when fully carried out and tested in all of its variations, we may ere long see the photo-electric plate competing, in high efficiency of conversion, with the dynamo-electric machine itself. I have also ascertained the causes of the frequent alterations in the electrical conductivity of selenium plates, and the conditions which will prevent them. I am now able to foresee the general properties of the plates, and indeed to give them such of the properties as I wish. I can cause a plate to show either an electromotive action or a higher conductivity, when exposed to light, or to show both properties. I can cause one surface of a plate to offer a higher resistance to a current than the other does, and can determine beforehand in which direction this action shall be exhibited. I can cause the resistance of a plate to increase and decrease in the same direction as the strength of the current is changed, or inversely; and can change the character of a plate by reversing its action in these respects, and re-reversing it, at pleasure. I have ascertained the *rationale* of the speaking and singing plates described in my paper read before the American Association for the Advancement of Science in September last. Some of the foregoing was known long before the date of my communication to Dr. Siemens, but it is all mentioned here in order to show that the principal points are already pretty well worked out and understood. For obvious reasons I do not yet publish my methods; but many points in the action of selenium do remain, which cannot yet be explained or accounted for.

In explanation of the slight irregularity in the action of the electro-motive plate mentioned, it should be stated that it had not been prepared for that purpose, but was sent to him as exhibiting another and entirely different property. During the development of that property, it had received some of the manipulations adapted for giving the electro-motive action, and in consequence thereof it could generate a slight current on exposure to light, although not with the uniformity of a specially prepared electro-motive plate. It should also be noted that "the south-eastern portion of a sky without clouds" (direct sunlight being cut off and excluded) is not a very intense source of illumination. But that fact will only render more satisfactory the proof of the reality of the phenomenon and its nature.

At the time of sending him the samples of my constructions, I had not a very large number of the electro-motive plates, and those were in almost daily use in experiments from which I hoped to deduce the philosophy of the action, so that they could not be spared, and I contented myself with pointing out that this plate could generate a current, sufficient, at least, to demonstrate its possession of that property. After having my papers, data and plates under consideration for nearly a year, Dr. Siemens, than whom there is no higher or better authority, has finally accorded the honor of first discovery to me. Whatever doubts or uncertainties may exist regarding the nature or cause of the phenomena adduced by other investigators, there can be none in this case, since all chemical, polarization and thermo-electric actions are here excluded from consideration, and the phenomenon is here unquestionably the direct conversion of the energy of light into electrical energy.

CH. E. FRITTS.

ELECTRIC CONDUCTIBILITY OF DISTILLED WATER AND GLASS.—G. Foussereau undertook an investigation of the electric resistance of water by Lippmann's general method. He found that specimens from the same laboratory and prepared in the same apparatus, on different days, presented specific resistances, at the temperature of 15°C., ranging between 118,900 and 712,500 ohms. The discrepancies seem to be attributable to substances dissolved from the linings of the vessels, to the solution of atmospheric matter, or to materials dissolved during the distillation. In order to study the first of these influences, he allowed the water to remain in the glass tube which was used for the experiment. For temperatures in the neighborhood of 15°C, there was an almost insensible diminution of resistance at the end of an hour, but reaching $\frac{1}{30}$ of the total value after 24 hours. Above 30°C, the solution of the salts of the glass became very much more rapid. At 75°, the resistance varied so quickly that measurements were almost impossible. Water raised to that temperature and rapidly restored to 15°, had increased its conductibility fourfold. After Foussereau's communication, Chevreul remarked that he had pointed out as early as 1843 the progressive dissolution of the alkalis in glass vessels by the water which is kept in them. For a long time he has employed in his laboratory only vessels of green glass for preserving distilled water or reagents which could be affected by those alkalis.—*Comptes Rendus*, July 15, 1884.

C.

THE TEHUANTEPEC SHIP RAILWAY.*

BY E. L. CORTHELL, Civil Engineer.

Vice-President FRED. GRAFF introduced Mr. Corthell, who spoke as follows:

In the certificate of membership in the Institution of Civil Engineers, of Great Britian, it is stated that the institution is "a society established for promoting the acquisition of that species of knowledge which constitutes the profession of a civil engineer, whereby the great sources of power in nature are converted, adapted and applied for the use and convenience of man."

In other words, the science of engineering is the adaptation of the laws of nature to the wants of man. As engineers, we should take a broad view of the scope of engineering science. The wants of man are varied, numerous and pressing. The laws of nature are given to us to unfold and apply to meet these wants and nothing short of their widest possible application and their greatest possible development is worthy of us or of the age in which we live. These wants are industrial, commercial, mental, social, moral and religious.

This subject, which we discuss to-night, is peculiarly international, affecting all the important conditions that relate to the welfare of the human race. Therefore, our horizon is bounded only by the limits of the abodes of man. From the map before you, and from the statements now to be given, the intimate relations existing between the subject in hand and the peoples of the earth, are manifest. Australia has an area of 2,449,000 square miles; Oceanica, which includes Australasia, Malayasia and Polynesia, has an area of 3,700,000 square miles, and a population of 35,851,000; the United States, without Alaska, has an area of 2,935,000 square miles, and a population of 55,000,000; Japan, with an area of only 169,000 square miles, has a population of 34,338,000; China, with an area of 3,922,000 square miles, has a population of 434,000,000; Hindoostan, with an area of 1,650,000 square miles, has a population of 240,000,000. To fully appreciate and understand the wants of these nations, and of their commerce, an intimate knowledge is requisite of the sources of trade, of supply and demand, of the handling of different varieties of products, of agriculture, manufactures and the mines; of the distance now traversed by the trade of one country with another; of the kind and amount of productions and trade of each country; the reasons for the trade of and with certain countries increasing or decreasing, and many other facts and conditions that affect the commerce of the world.

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* An address delivered before the Franklin Institute, December 28, 1884.

It would be out of place here to enumerate the great number of details that go to make up the general items of the commercial estimate. A few only are mentioned to familiarize you with the subject. The United States has a feeble commerce with the United States of Colombia on the west coast of South America, carried on either over the Panama Railroad or around Cape Horn. It imports from that country coffee, barks, hides and India rubber, and exports to it iron, steel, machinery, lard, cotton goods, flour, paper, etc. With Peru, it has a trade in soda and guano, and exports to it cereals, machinery, woods and mineral oil. Strange to say, on account of the difficulties in trading at present with this country, many of the articles are shipped from Peru to France on French steamers, and then re-shipped to New York. We have a similar trade with Chili. Our China trade, either across the continent by rail, or by the Panama Railroad, Cape Horn, Cape Good Hope, or Suez Canal, is imports of tea, silk, rice, palm leaf, jute and hemp, and exports of cotton cloth, mineral oil, etc. We have about the same character of trade with Hong Kong and Japan. With Australasia we have the foundations of a diversified trade to be built up when the ship railway is completed. The principal imports from that country to the Atlantic Coasts of the United States are gums, tins, coal and wool. The principal exports are locomotives, machinery, iron manufactures, household furniture, agricultural implements, illuminating oils, barley, carriages, trunks, sewing machines, linen and cotton goods, books, etc. The most important manufactures exported to that country are twenty-seven in number. With the various groups of islands in Polynesia we have a diversified trade. There is, with the Sandwich Islands alone, a commerce of over six million dollars. We receive from them brown sugar, rice and limes, and send them the same general class of goods that go to Australasia. England, France and other European countries, have a nearly similar commerce with the countries mentioned.

It is necessary now to glance at the internal commerce of the United States, because from that we can estimate what its foreign commerce would be, if the barriers now obstructing it were removed, and if the immense surplus products, agricultural, manufacturing and mineral, could be shipped at a reasonable expense and in a reasonable time, to foreign countries needing our surplus productions. During the year 1883, the railroads of the United States transported over four hundred million tons of freight, valued at over $10,000,000,000. These goods if placed for transportation in one freight train, carrying fifteen tons. to the car, would require a train 175,000 miles long, or seven times the circumference of the earth. In addition to this rail transportation there should be added many millions of steamboat and coastwise tonnage, probably equal to fifty per cent. of that transported by rail. While we are carrying, year by year, these immense amounts of freight, the whole foreign commerce of Europe is less than ten billions of dollars in value.

The Mississippi Valley has a commercial internal business, by river and by rail, of over four billions of dollars. Galveston, the seaport of Texas, has a tributary net work of railroads more than six thousand miles in length. The increase of commerce of the countries west of the United States, that is, those bordering on the Pacific, has been one hundred and fifty per cent. in five years; but on account of the impossibility of reaching this business we have less than four per cent. of it—the remainder going to Europe, via the Cape of Good Hope and the Suez Canal.

Our Pacific Coast, California, Oregon and Washington Territories, is especially adapted to the cultivation of cereals, particularly wheat. The salubrity of the climate and the richness of the soil reduce the cost of raising it to a minimum. But on account of the great length of the voyage by which the wheat and the flour of the Pacific Coast reach Liverpool and the other markets of the Old World, it is impossible to compete with the wheat raised in India and Australia. A voyage of sixteen thousand miles, is necessary to place the wheat in the Liverpool market. The cost per ton is about $15.00. To haul it across the continent by the transcontinental railway lines, would cost $25.00 to $35.00 a ton to New York alone, saying nothing of the Trans-Atlantic voyage. An idea can be obtained of the immense distances by which commerce now moves on its main lines by an examination of the table of comparative distances on pages 483–484.

The Mexican *Financier* in a recent article, used the following language:

> "The Rocky Mountains of the United States, the Sierra Madre of Mexico, the Cordilleras of Central America, and the Andes of South America, form an almost continuous barrier, so lofty and extensive, as to be nearly impassible to man in his commercial pursuits. The railways that scale these

heights by an immense expenditure of money, seeking the business of the fertile valleys on each side, rise to an altitude of several thousand feet, soar up among the clouds, climb over the rocky barrier and descend the mountain sides by grades almost impracticable for the heavily loaded trains. These mountain barriers separate at least seventy millions of people living in Mexico, the United States and Canada, nearly all of whom would be benefited by the breaking down of this obstruction in their agricultural, manufacturing and commercial prosperity.

" To sum up these general statements, and to bring together these various features of the subject, the world needs a gateway through the mountains, a path broad and plain for the inter communications of the nations, on the shortest possible lines, for the transportation of the varied products which each nation has in surplus for the others' needs. More than most other nations, does the United States require that extension of her coast line from the east to the west, and the west to the east, which a navigable connection between the Gulf of Mexico and the Pacific will give her. More vitally still, though the magnitude of the commerce is less, does the Republic of Mexico need a union of her east and west coast lines across the Isthmus of Tehuantepec, as an auxiliary to the extensive and necessary railway system which this young republic has so heroically inaugurated at great present sacrifice, but for the future greatness and prosperity to which her wonderful natural resources entitle her."

When it is known, that the distance by rail from New York to San Francisco is about 3,300 miles, and that the Pacific can be reached from New York at the Isthmus at Tehuantepec, by an all-water route, nearly one thousand miles shorter, and that seventy per cent. of the Asiatic Pacific business and Australasian trade lies south of the latitude of Tehuantepec, the commercial necessity for the breaking down of the barrier between our Atlantic Coast and these countries is fully appreciated.

Particular attention is directed to the unfortunate position of the Mississippi Valley and its outlet, and the whole coast of the Gulf of Mexico, extending to Vera Cruz. This whole country is hid away as it were, and isolated from the countries to the west of it, and yet with inter-oceanic communication, it will be brought into close proximity to these countries. The immense surplus productions of the Mississippi valley and of the country contributory to the Gulf Coast, will then find a market on the western coast of South America, or our own western coast, or the Isles of the Pacific, or the far Pacific countries—Japan, China and Hindoostan.

Turning to the subject of manufactures, it may not be generally known that while immense quantities of goods of all kinds are turned out annually, the amount exported is insignificant. We manufacture

$420,000,000 of iron and steel; $185,000,000 of leather goods; $202,000,000 of woolen goods; $246,000,000 of cotton goods; $41,000,000 of silk goods; $24,000,000 of glass and similar products. But of all this immense amount of manufactured articles, we export not over *three per cent.* And yet the country at this present time, is passing through a period of very great business depression said to be largely due to *overproduction.* With the markets of the world open to these surplus productions and the exports increased from three to even twenty per cent., the business depression will pass away. This permanent avenue of commerce will so regulate production and business in the future, as to place these periods of depression further apart and make them less injurious to the country.

The *London Times,* of August 21, 1884, in closing a very accurate description of the Tehuantepec Ship Railway project, uses the following very forcible language in reference to the benefit to commerce and to the world, which will surely come by the opening of this interoceanic communication:

> "Looking at the ship railway project from a broad and general point of view, there can be little doubt that it is one which is fraught with great results. This will be better realized when it is remembered that the American Isthmus separates about 100,000,000 of the most enterprising, industrious, and enlightened people on the face of the earth, inhabiting the north Atlantic Coasts of Europe and America, from 600,000,000 who inhabit the Orient and the Islands of the Pacific. It is true that the sailing distances which separate England from India, China, and other oriental countries, have been greatly reduced by the Suez Canal; but these distances are almost insignificant when compared with those which the ship railway would annihilate. For instance, the greatest saving effected by the Suez Canal between London and Calcutta is about 4,500 statute miles; whereas the sailing distance by the ship railway from London to every port on the Pacific Coast of North America will be lessened by nearly twice this great distance, or about 8,250 miles. The Suez Canal brought London and Canton about 3,500 miles nearer together by sea. The ship railway would save more than three times that distance between the great American metropolis and every port in British Columbia. The American Isthmus and the Cordilleras of North America constitute a narrow, but almost impassible barrier to the interchange of the manufactures and productions of forty millions of people in the Mississippi Valley and the Atlantic States, not only with those of 10,000,000 of their countrymen to the west of them, but with the others on the islands and coasts of the Pacific who are seemingly their nearest neighbors. The ship railway would give to these descendants of the British Isles a sea route between their Atlantic and Pacific ports, scarcely a thousand miles longer than the railway between New York and San Francisco, and it would give to the vast Valley of the

Mississippi a gateway equivalent to the discharge of its mighty river directly into the Pacific. A work designed to confer such great benefits on the commerce of the world should commend itself with special force to this country, which is carrying more than seventy per cent. of that commerce."

THE GENERAL HISTORICAL DEVELOPMENT.

The early navigators and discoverers of America had for their object in their perilous voyages across the Atlantic, in their small ships, the discovery of a new route to the East Indies. Whenever these adventurous rovers landed on the Coast of North or South America, they immediately searched for a passage through the land towards the Indies. Over 300 years ago, Cortez attempted to pass through the Isthmus of Tehuantepec in his search for a passage to this coveted country. From that time to this, there has never been a moment when an interest in this interoceanic transit was not felt by all the commercial nations of the world. The growth of the great nation founded by the English in North America, whose millions partly on the Atlantic and partly on the Pacific Coast, are separated by mountain ranges, has made this necessity still greater until the time has arrived when its welfare and even prosperity is dependent upon this connection between its east and west coasts. Many surveys have been made; many projects brought to the attention of different nations; much money has been expended; governments have attempted to devise plans for overcoming this barrier to commerce; and it has been the study of the leading commercial and engineering minds of the world to present some practicable plan for meeting this great necessity of commerce and of the world. The question is forcibly and briefly put by the "London Engineering," in its issue of January 9th, 1885, as follows:

"The idea of carrying across the Isthmus of Tehuantepec, the commerce which flows backwards and forwards between the Atlantic and Pacific and Indian Oceans, was already old when the Pilgrim Fathers planted on the American continent the nucleus of a great nation. Cortez himself, sought for a natural way along the rivers which flow in either direction to the sea, and finding none, he purchased large tracts of land as an inheritance to his posterity, confident that in time the needs of the world and the advance of science, would carry a highway over this very spot. His descendants still hold these lands, which lie in the exact track settled by recent surveys as the route for the proposed ship railway, and thus they will reap the fruits of a piece of statesmanlike far-sightedness, which stands in remarkable contrast with the timidity and supineness of a generation which, having seen more marvels of science and engineering than the whole human race which preceded them, can scarcely be got to believe that it is possible to raise a laden ship out of the water without breaking her back. During the three centuries that have elapsed since Cortez in his imagination, saw his grandchildren levying toll upon the oriental traffic which has enriched one nation after another passing, successively through the hands of the Arabians, the Phoenicians, the Venetians, the Portugese, and the Dutch, until it finally settled in England, the idea of cutting or crossing the narrow Isthmus which connects North and South America has never been long forgotten, and for the last quarter of a century there have always been some ardent minds at work upon it."

Not only have engineers had this subject in mind during these centuries, but the statesmen of this country and of Mexico have realized the great importance of an interoceanic transit, and have sought for it by various means—by concessions to companies formed for the purpose of constructing railroads or canals, and by treaties between the countries interested, uniting them as governments, in the construction of a transit-way. As early as 1835, President Jackson made inquiries into the state of the projects for uniting the Atlantic and Pacific Oceans through the Isthmus of Darien. In 1839 an elaborate report on the whole subject was made by the Hon. C. F. Mercer, of the House of Representatives. In 1846, the Secretary of State communicated to the Senate a number of valuable papers on the subject. In 1849, there was presented by the Hon. J. A. Rockwell, a report embracing 658 pages bearing on this subject. Including among the papers were reports of the surveys of the Isthmus of Tehuantepec, of Nicaragua and of Panama, and in relation also to the then proposed Panama Railroad. In 1851, President Fillmore said in his message to Congress, "in investigating upon this important subject, this government has had in view one and only one object. That object has been, and is, the construction or attainment of a passage from ocean to ocean, the shortest and best for travelers and 'merchandise, and equally open for all the world." Succeeding Presidents have taken up the subject and discussed its geographical and political features, and urged the construction of a highway from ocean to ocean. President Hayes in 1880, in his message to Congress stated the importance and necessity of this interoceanic communication across the American Isthmus, in the following forcible language:

"An interoceanic canal across the American Isthmus will essentially change the geographical relations between the Atlantic and Pacific Coasts of the United States, and between the United States and the rest of the world. It will be the great ocean thoroughfare between our Atlantic and our Pacific shores, and virtually a part of the coast line of the United States, Our merely commercial interest in it is greater than that of all other countries, while its relations to our power and prosperity as a nation, to our means of defense, our unity, peace, and safety, are matters of paramount concern to the people of the United States."

Coming down to the present time, there is probably no stronger statement of this question, than that given recently by President Arthur, who speaking of the necessity for interoceanic communication, says:

"It is imperatively demanded by the present and future political and material interests of the United States. The establishment of water communication between the Atlantic and Pacific Coasts of the Union is a necessity, the accomplishment of which, however, within the territory of the United States is a physical impossibility. While the enterprise of our citizens has responded to the duty of creating means of speedy transit by rail between the two oceans, these great achievements are inadequate to supply a most important requisite of national union and prosperity. For all maritime purposes, the States upon the Pacific are more distant from those upon the Atlantic than if separated by either ocean alone. Europe and Africa are nearer New York, and Asia is nearer to California than are these two great States to each other by sea. Weeks of steam voyage, or months under sail, are consumed in the passage round the Horn with the disadvantage of traversing tempestuous waters or risking the navigation of the Straits of Magellan. A nation like ours cannot rest satisfied with such a separation of its mutually dependent members. We possess an ocean border of considerably over ten thousand miles on the Atlantic and Gulf of Mexico, and including Alaska, of some ten thousand miles on the Pacific. Within a generation the western coast has developed into an empire, with a large and rapidly growing population, with vast but partially developed resources. At the present rate of increase, the end of the century will see us a commonwealth of, perhaps, nearly a hundred million inhabitants, of which the west should have a considerable larger and richer proportion than now.

"From a purely commercial point of view the completion of such a waterway opens a most favorable prospect for the future of our country. The nations of the Pacific Coast of South America will by its means be brought into closer connection with our Gulf States. The relation of these American countries to the United States is that of a natural market from which the want of direct communication has hitherto practically excluded us. By piercing the Isthmus the heretofore insuperable obstacles of time, sea, and distance disappear, and our vessels and productions will enter upon the world's competitive field with a decided advantage of which they will avail themselves. When to this is joined the large coasting trade between the Atlantic and Pacific States, which must necessarily spring up, it is evident that this canal affords even alone, an efficient means of restoring our flag to its former place on the seas. Such a domestic coasting trade would arise immediately, for even the fishing vessels of both seaboards which now lie idle in the winter months, could then profitably carry goods between the eastern and western States.

"The political effect of the canal will be to unite closer the States now depending upon railway corporations for all commercial and personal intercourse, and it will not only cheapen the cost of transportation, but will free individuals from the possibility of unjust discrimination. It will bring European grain markets of demand within easy distance of our Pacific, and will give to the manufacturers on the Atlantic seaboard economical access to the cities of China, thus breaking down the barrier which separates the principal manufacturing centres of the United States from the markets of the vast population of Asia, and placing the Eastern States of the Union for all purposes of trade midway between Europe and Asia. In point of time the gain for sailing vessels would be great, amounting, from New York to San Francisco to a saving of seventy-five days; to Hong Kong of twenty-seven days; to Shanghai of thirty-four days, and to Callao of fifty-two days."

In reference also to the business of Europe which will be affected by an interoceanic transit, Prof. J. E. Nourse, in his valuable work on the Suez Canal says in relation to the advantages which a crossing at the American Isthmus would have:

"It may be conceded that a portion of the sailing tonnage of Europe, trading with China, Japan and Philippine Islands, Borneo, Celebes, New Guinea, Australia and possibly Java and Sumatra, would pass through the route. Besides these countries, the western coasts of South America, and especially the California interests must come into view. A ship canal across our Isthmus would probably develop on these coasts, and under our advancing relations with China and Japan, new activities in commerce, equal if not superior to those which have been stated as stimulated by the opening of the Suez route."

Other important opinions might be given from men who have carefully studied the whole commercial subject to show the advantages which would accrue not only to this country, but to other countries of the world, by cutting through or going over the American Isthmus; but enough has been said to convince any one that the time has arrived for the work to be done, for the connection between the oceans to be made. It may be stated that the statesmen of Mexico from Cortez to the present distinguished President of Mexico, General Porfirio Diaz, have all been aware of the immense benefit to Mexico that would inevitably result from an inter-oceanic crossing at the Isthmus of Tehuantepec—one of the States of Mexico.

PRACTICABILITY OF THE SHIP RAILWAY.

Every project takes its position in the minds of men, according to the standing of the projector. This model which you see before you is the expression of the thought and the study of one of the best civil and mechanical engineers of the world—Mr. James B. Eads. His name is known to you by reputation, and it need only be said here, that from early life his attention and his work have been in the direction of civil and mechanical engineering. With the opportunities for only a meagre education in his youth, he has risen by study and observation of the laws of nature to his present position before the world. His achievements have been remarkable, and mark him as a man of genius. When the country was in the throes of rebellion he was asked by the Government to build seven powerful iron-clad steam-boats for use on the western rivers, and fit them with an exceptionally heavy armament all in one hundred days. The work was accomplished—although when he commenced, the wood with which they were built was standing in the forests and the iron was in the ore. In his business, later, in lifting the wrecks of steamboats, he examined the bed of the Mississippi River as no one else has had the opportunity of doing. The laws of nature as observed in that work by him, led him in later years to propose the improvement of the mouth of the Mississippi River by means of jetties, which have abundantly proven his theories to be correct. The bridge he built over the Mississippi River at St. Louis at a time when deep foundations were very rarely attempted, going down as they did, through 115 feet of shifting quicksands to the solid rock bed of the river, proved his knowledge of river hydraulics and constructive engineering to be sound, theoretically and practically. The bridge will stand forever as a monument of his genius, but his work and his fame are not confined to his native land. Canada, Brazil and England have called upon him for the solution of difficult problems in Engineering, and he was recently awarded the Albert medal by the Society of Arts of Great Britain—the only American who has received it. This subject, therefore, on which he has expended so much thought and study for the last five years is not the project of some irresponsible, unknown inventor, but of a man of genius, who has accomplished great things and whose inventions are acknowledged to be useful to individuals and to governments. This model illustrating this subject will speak to you more eloquently than it is possible for me to do.

Before explaining it to you, I will say that the subject of the transportation of ships is not a recent one. It was accomplished, as is well known, by the Athenians 400 years before Christ, when they transported their war ships over the Isthmus of Corinth; in the middle ages, by the Turks who transported ships of war in a similar manner; by Swedenborg, one hundred years ago in transporting three vessels of war across one of the peninsulas in the Baltic; and before the construction of the Suez Canal was commenced two noted English engineers, Brunlees and Webb, proposed a ship railway and made their plans for the work. It should, however, be stated, that the work that has been accomplished so far in moving vessels over land, has been on a small scale. The plans for the Tehuantepec Ship Railway are illustrated by this working model made, according to scale, from the plans of the full sized works.

At each terminus a basin is excavated, leading on the one side from the river, and on the other, from the lake, to a dock, which will be walled on the sides and on one end either by masonry or by timber. In this dock a pontoon will be placed, which, like an ordinary lifting dock, will be capable of raising the vessels. This pontoon will be made of steel plates, with bulkheads athwartships, and fore and aft, so as to give it the strength required to support the weight that it has to carry when out of the water. Its size will be about 450 feet in length, 75 feet in width and from 12 to 15 feet in depth. There will be connected with it on each side a water-tight tower, whose top stands above the surface of the water when the pontoon is submerged and grounded on the foundations of the dock. The pontoon is sunk by opening sluice gates; these sluice gates are in its side or bottom and are operated from the top of these towers. It is raised by means of powerful pumps which withdraw the water from the pontoon and discharge it into the surrounding dock or basin. These pumps as designed are sufficiently powerful to raise the pontoon with the largest vessel upon it in from 15 to 20 minutes. It is guided in its vertical movement by large anchor rods or weighted cylinders, which are securely anchored in the foundations of the dock. These rods pass freely through the pontoon, but are separated from its water spaces. The heads of these guiding rods or cylinders prevent the pontoon from rising above a certain level, and also resist its buoyancy when the vessel has been run off on to the railway. In order to lift a vessel without injury to itself and to place it upon a cradle or carriage for transportation without any possible injury to this carriage, it is necessary to distribute or equalize the unequal weight of the vessel so as to bring no more load upon one part of the carriage than upon another.

A vessel has not the same weight per unit of its length throughout its whole extent, but being a girder capable of resisting the flexures and distortions which it must necessarily undergo in its voyage on the ocean, it is capable of sustaining without injury to its structural integrity, the equalization which it is necessary to make. In fact, when the vessel is in its natural element, smooth water, it is not equally borne by the water per unit of its length, from the fact that certain parts of the vessel have more buoyant power than other parts; for instance, the bow and stern of a steamer, or of any vessel have a tendency to droop, and it is often the case that after they have been built some years the ends of the keel are found to be below the central part. The equalization is accomplished by a system of hydraulic rams or presses which are built into the pontoon, and are founded upon a second deck about six feet below the main or upper deck. These rams are arranged in longitudinal and lateral lines, the latter being spaced about seven feet apart. The combined or total area of the rams in any one lateral line is exactly equal to the combined area of every other lateral line. There being seven rams in one of these lateral lines in the amidships section of the vessel, their area, if combined into one ram, would be exactly equal to the one ram under the bow or stern of the vessel. Approaching the bow or stern from the centre there are five rams in a lateral line; approaching still nearer the bow or stern there are three rams in each lateral line, and under the bow or stern there is one ram. These rams are all connected by means of water pipes, through which a pressure is applied to the whole system of rams, by means of a hydraulic pressure pump placed on the top of the towers on the side of the pontoon. These rams have a vertical movement of seven or eight feet. When the principle of hydrostatic pressure is understood it will be seen that any mass, whatever may be its shape, that rests upon this system of hydraulic rams when they are under pressure will be equally borne throughout its whole extent, providing it has a bearing upon all the rams in the system. In the case of a vessel, either a sailing ship or a steamer, this equalization is so perfect that the excess of weight in the central portion of the vessel, when she is loaded, will be taken up by the lines of rams towards the bow and the stern, which have immediately over them a weight less than that which they are able to sustain. This system of rams is grouped by means of valves so that a greater pressure, if necessary, can be brought to bear upon one part of the vessel than upon another. In practice there would be a large number of valves so that the system could be applied to different sizes and shapes of vessels as each might require. It will be seen, therefore, that when the vessel rests upon this system of rams she is water borne, for she is resting upon so many columns of water under pressure, which equalize the weight of the vessel by a process which is similar to that employed by nature herself when the vessel is resting in her natural element. A pressure gauge is attached to the water pipes which will serve to show the exact weight of the mass that is borne on the system of rams.

As a body immersed has no stability, the pontoon which raises and lowers the vessels has no stability under water. As it will not always be possible to bring the centre of gravity of the vessel directly over the centre of the pontoon, there will be a tendency for the pontoon to come up out of level if there is more weight upon one end of it than upon the other. This probably would prevent the pontoon from rising by its binding upon the anchor rods which guide it. To prevent this the pontoon is balanced, not by water let into the compartments as in the case of a balance dock, but by a mechanical appliance called a hydraulic governor. These governors are located at the four corners of the pontoon and at other points along the side of the pontoon, if it should be found to be necessary in practice. They consist of a plunger working in a cylinder. The plungers are attached to the pontoon, and the cylinders to the dock outside. On each corner there is an inverted and an upright cylinder. The upright and inverted cylinders on the diagonal corners are connected with each other by means of pipes. The cylinders and the pipes are water-tight and are filled solid with water. Now, if there is, say 100 tons more weight upon one end of the pontoon than there is upon the other end, there will be brought upon the water in each of the two inverted cylinders at the heavy end of the pontoon a weight of 50 tons. The pressure due to this weight is immediately transmitted through the pipe to the upright cylinder on the diagonal corner, and the water in the top of this cylinder instantly reacts with a 50 ton pressure, as a plunger upon the metal plunger in the cylinder, and thus compels this corner of the pontoon to go up or down with the same velocity and to remain at the same level as the diagonal corner of the pontoon with which it is connected ; the same of the other corners. By this means the pontoon is made to rise and fall in a perfectly level plane, and consequently is always balanced so as to move freely upon the guiding rods. A pressure guage attached to the governor pipes will indicate the total excess of weight on either end of the pontoon. If it is too great for the governors to balance with safety or for the rams to equalize, the pontoon would be lowered and the position of the vessel shifted. On the deck of the pontoon and between the longitudinal lines of the rams are laid the rails for the carriage which is to transport the vessel. These rails are six in number and constitute three ordinary gauge tracks, each 4 feet 8½ inches. The outer rails are 29 feet apart between gauge lines. The carriage to transport the vessel is built of steel girders. As the vessel itself is a girder it cannot be easily bent out of its position, and as the rails resting upon an immovable road-bed are another girder, and the carriage simply moves between these two girders, its greatest strength is in its cross girders, the longitudinal girders being only of sufficient strength to carry the trucks which are placed under them. The cross girders are spaced about seven feet apart, exactly like the rams in the pontoon. They are supplied with a system of supports for the vessel, keel and bilge blocks. The keel block is continuous the whole length of the vessel, and is hinged in such a manner as to be adjustable to the shape of the vessel's keel. The supports under the keel block and the other supports of the vessel rest upon large steel rods, in which a thread is cut for an adjusting nut which can be run up or down on the rods. The upper end of these rods under the bottom and bilges of the vessel is supplied with an adjustable hinged surface which is arranged to move either way so as to be in effect hung on an universal joint. These surfaces have an area of about 12 square feet, and are cushioned with rubber or other material that will prevent injury to the vessel when it rests upon the supports. When these supports are in position they may be said to resemble in general shape an ordinary music stand.

The process of lifting a vessel is as follows: The carriage is run from the railway upon the pontoon and locked in exact position upon it. The water is let into the pontoon by sluice gates, and it goes down with the carriage resting upon it until it rests upon the foundation of the dock, or at a sufficient depth in the water to allow the vessel to be floated in over it without striking the supports of the carriage, which are previously let down by means of the adjusting nuts until the heads of the supports rest upon the girders of the carriage. The vessel is then brought in over the pontoon, and is located as near as possible with its centre of gravity over the centre of the pontoon. Adjustable guides from the side of the dock, working by hydraulic power, quickly and gently bring the vessel to a position centrally over the carriage; that is, its keel is directly over the keel block of the carriage. The pontoon pumps are now set at work, and the pontoon with the carriage upon it comes up under the vessel; just before coming in contact with it the hydraulic pumps on the towers of the pontoon, which actuate the rams, are set at work and they gently force up under the keel, the bottom, bilges and sides of the vessel the whole system of rams. The valves are then closed to prevent the water pressure from escaping from under the rams, and the pontoon pumps to lift the pontoon up out of the water with the vessel on it. As the vessel rises up out of the water, resting upon the system of rams, its weight becomes greater and greater upon them every moment, some of them being slightly depressed, some slightly elevated, and the equalization through the system goes on as the vessel rises, until when it is entirely out of the water its whole weight is distributed from stem to stern. While it is resting upon the supports, which also, as we have seen, rest upon the rams, the adjusting nuts are run down on the thread of the supports until they have a firm bearing upon the plates of the cross girders. When this adjustment has been made, which would require only a few minutes by expert men to accomplish, the valves are opened, the water pressure escapes from the rams and they recede downwards into the pontoon. The weight of the vessel has now been transferred from the rams to the carriage, and the equalization of the weight upon the carriage is as perfect as it was upon the rams themselves. Now as the girders of the carriage are spaced the same as the lateral lines of rams, if we arrange the same number of wheels with each girder, we then will have the same weight imposed upon every wheel, which is intended to be not over 8½ or 9 tons, which they will be able to sustain, for each wheel will be tested to 20 tons when it is manufactured. As it is a common practice of the railways of this country, and especially in England, to impose a greater weight than this upon the driving wheels of locomotives, it will be seen that this is an admissible load for the wheels.

The wheels will be arranged in a truck of very simple form. As it is necessary for the carriage to move on practically straight lines, the wheels can be arranged with two flanges instead of one as a precaution against derailment, though the breaking of one wheel or of several wheels will not effect the integrity of the carriage. With each wheel is a powerful spring which will also be tested to 20 tons before closing. It has a vertical movement of six inches. When the maximum load of a 5,000 ton weight is placed upon the carriage these springs will be closed to within three inches. This gives an elastic bearing for the vessel and the carriage, and will serve two purposes; one to take up any slight irregularities there may be in the track, and the other to prevent any possible jar to the carriage or the vessel. When the load has been equalized upon the carriage it is evident that there will be no more weight brought upon the rails at any point than there is brought upon them by a locomotive on an ordinary railway. So that as far as the strain upon the rails is concerned, a rail of ordinary dimensions would answer the purpose. But as there is an immense concentrated and rigid weight to be moved, great strength and stiffness will be given to the whole superstructure, and the rails will weigh from 100 to 120 pounds per lineal yard, that is, they will be about twice as heavy as an ordinary railroad rail. These rails will be of steel and will rest upon long steel ties which extend under the whole six rails of the railway. They will be made of broad steel plates with a large bearing surface, and will be fastened securely to the rails. They will rest upon the best quality of stone ballast, or perhaps in some cases upon longitudinal timbers set into the ballast, or into concrete. The road-bed itself upon which this perfect superstructure rests will be constructed of the very best materials obtainable and in the most thorough manner. The embankments especially will receive the closest attention, and the greatest pains will be taken in order to secure a perfect and unyielding road-bed. Its width will be from 45 to 50 feet, so that there will be a wide shoulder outside the ends of the steel plated ties.

The motive power for hauling the loads will be locomotives of great traction power, which will have imposed upon the driving wheels at least 100 tons. As is readily seen, these locomotives can be attached directly to the load, three in front and three behind as pushers, if necessary. As the maximum load will be only 5,650 tons, it will not be difficult to haul it over the grades of the railway. The ordinary consolidated engines of the day will haul from 1,500 to 2,000

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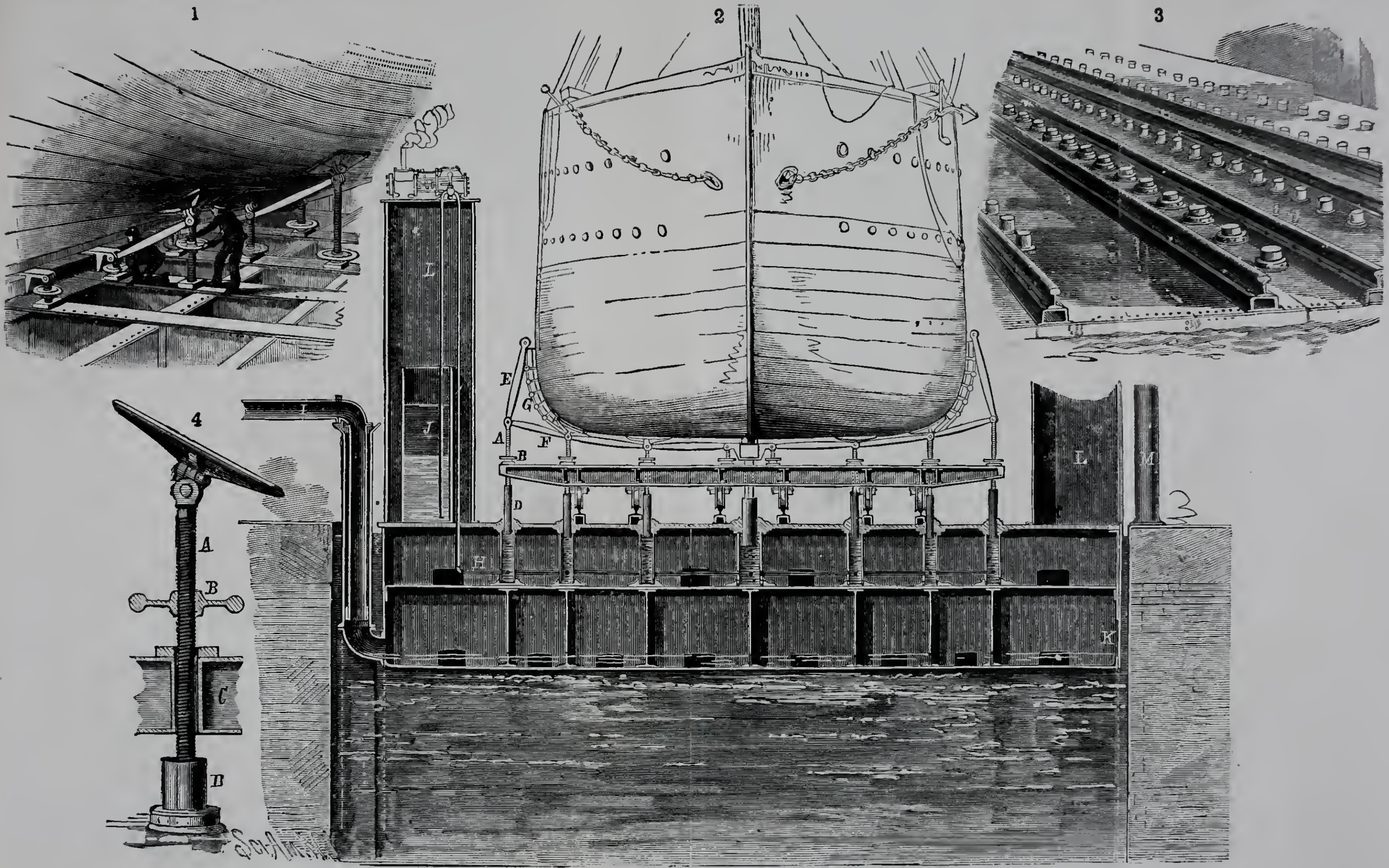
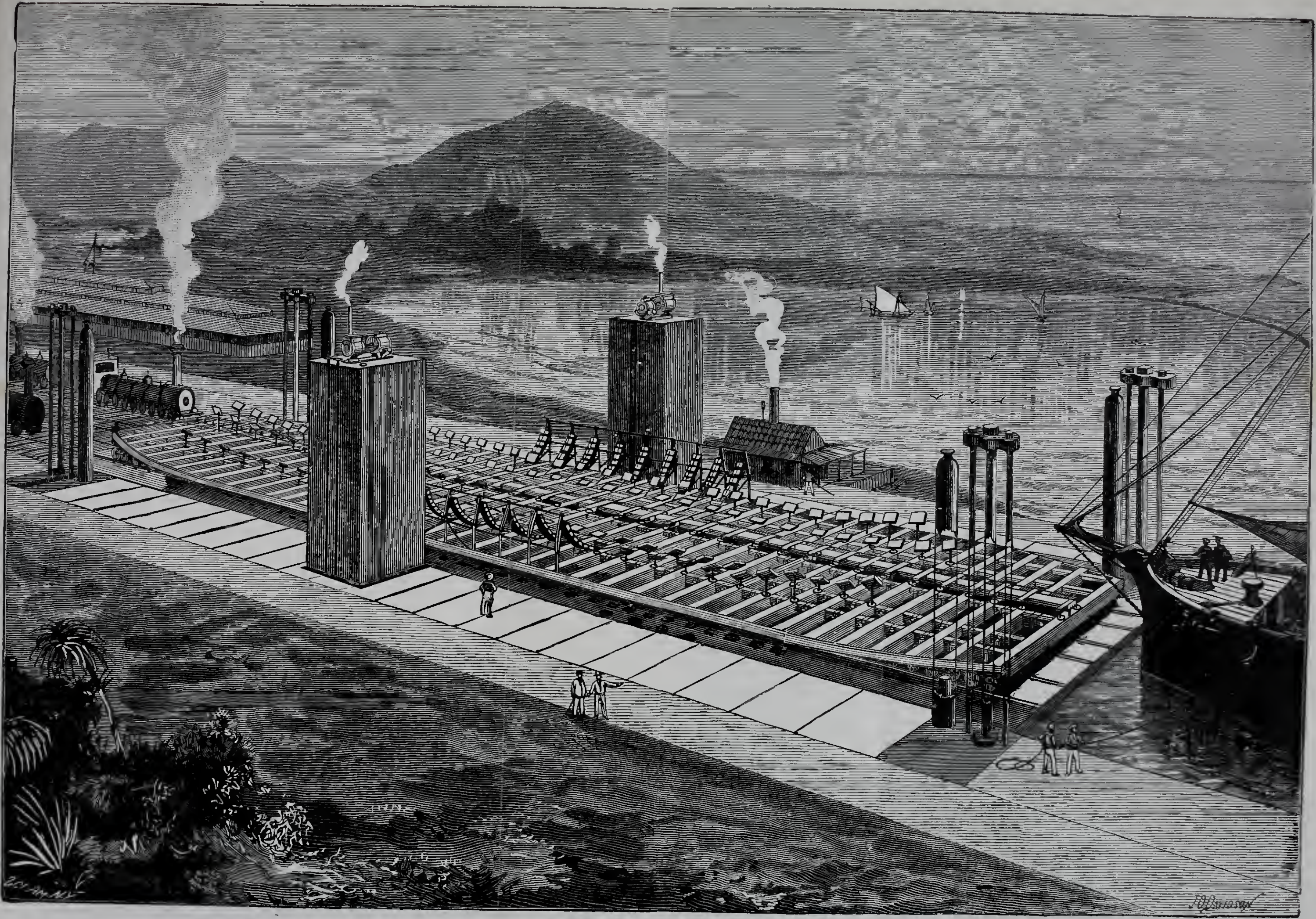
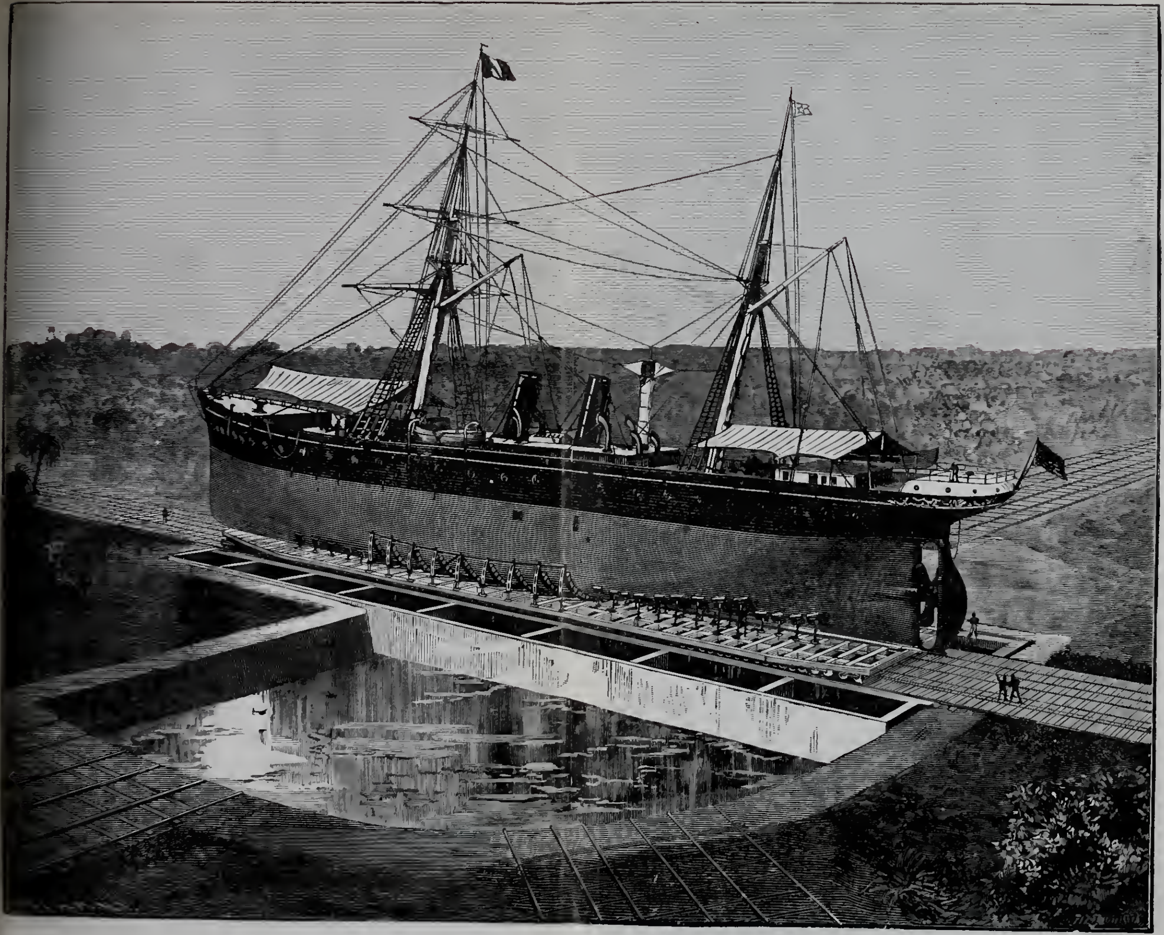
Corthell. Plate I.



THE INTEROCEANIC SHIP RAILWAY.—SECTIONAL ELEVATION AND DETAILS OF PONTOON AND RAILWAY CRADLE.

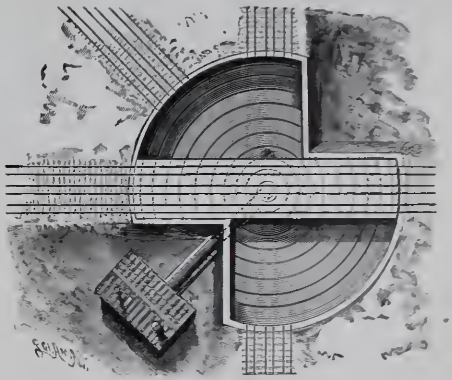


THE INTEROCEANIC SHIP RAILWAY.—THE LIFTING PONTOON AND RAILWAY CRADLE.
[PERSPECTIVE VIEW.]

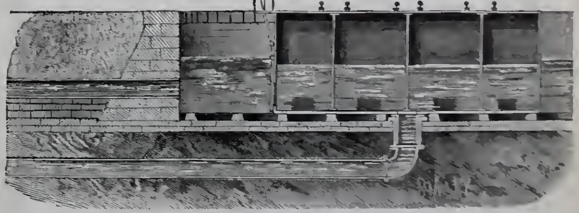


The Interoceanic Ship Railway.—The Floating Turntable.

PLAN.



SECTIONAL ELEVATION.



tons without difficulty over grades up to twenty feet to the mile. Three such ordinary engines would, therefore, haul the maximum load; but with locomotives of double the power of these engines, no difficulty is apprehended in performing the work required, and at a fair rate of speed, which should not be less than from 8 to 10 miles per hour. As it has already been said, a carriage constructed after the manner described must necessarily move on practically straight lines, not perfectly straight, because it is ascertained that a movement in the journals of the wheels, and on their treads, will permit the use of a curve of 20 miles radius, which is practically a straight line. At points on the line, where such a curve as this would necessitate very heavy construction work in the shape of mountain cuttings or very high embankments, a change of direction to avoid them will be made by means of turntables. These turntables are very simple and economical in construction, maintenance and operation. They admit of a change of direction to any extent, and it is found that by their use a large amount of money is saved in construction. The location of the railway, which has been made with great care by instrumental surveys and detailed examinations of the country, is, through the rougher portion of the Isthmus, along a succession of valleys between high hills and mountains. In order to pass from one valley to another and take advantage of the natural lines of the country, these turntables are employed. Five of them only are necessary. They are built as follows:

A segmental basin of masonry is arranged to receive a pontoon. This pontoon is centred in the basin so that it will revolve around a central column, although it does not rest upon this column. When not revolving, the pontoon rests upon concentric bearing surfaces in the bottom of the basin. In order to turn a vessel it is run upon this pontoon; the water is then pumped out from the pontoon into the basin by means of a powerful centrifugal pump, until the pontoon rises sufficiently to be lifted from its bearing surfaces. It is, then, by means of stationary engines, worked by a cable or other means, turned about the central pivot, while floating upon the water until the rails on the deck of the pontoon correspond in line with those of the railway in the new direction. The water is then admitted to the pontoon by means of sluice gates or valves, until it grounds upon the concentric bearings in the bottom of the basin. The vessel is then run off the pontoon upon the railway. When it arrives at the next point where a change of direction by this means is to be made, the same operation turns the vessel in another direction. At three of the five turntables, examinations show that water under a head from the mountain streams can be used to perform the work without the use of pumps. These turntables, while they are a necessity, will be utilized for two very important purposes; one for meeting points for vessels moving in opposite directions. A vessel moving from the Gulf of Mexico towards the Pacific meets another vessel at one of these turntables coming from the Pacific, by being run across the turntable on its arrival on to an extension of the track. The turntable is then revolved to take on the vessel coming from the other direction and it then goes on its way. The first vessel is then run back upon the pontoon and sent in its direction, the whole movement occupying but a short time. It will be seen that the weight of the vessel having been equalized upon the carriage by the hydraulic rams, if the centre of the carriage is brought over the centre of the pontoon, the latter will be balanced when it rises from the bearing surfaces in the bottom of the basin; but if the pontoon is not exactly balanced it can be brought level by letting water into one or more of the compartments on one end or the other of the pontoon. The second purpose, that the turntables will subserve, will be as dry-docks, where vessels can be run out on radial tracks built on each side of the segmental basin, where they can be cleaned, painted or repaired, as the case may be, and where they can remain as long as necessary. As every iron ship should be taken out of the water twice a year, the expense of docking will be saved, which is considerable for a large vessel. There will be one of these turntables at each terminus of the road near the dock, to facilitate the handling of the business at those points, and they will be located also at other points on the line where the operation of the road may show meeting points for vessels to be required.

The changes in grade on the railway will be made by very flat vertical curves. The elasticity of the vessel itself and the movement of the springs will allow a change vertically of two inches or more in four hundred feet. A curve established on this basis has been applied to the working profiles of the railway and found to be perfectly practicable in the construction of the railway.

The objections sometimes made to hauling laden ships overland are, first, that the vessel is out of its natural element; but it must be borne in mind, as we have already stated, that a vessel in her natural element and even in a smooth sea, not buffeted by the waves, is not equally borne And then, when we consider the condition of the vessel when her natural element is disturbed, as it is almost always in a voyage, you will readily see that the strains of all kinds, twisting, bending, tortional and by flexures up and down, by shocks to her plates and rivets by the impact of the waves, by the bursting effect of her cargo (if there is any) by the sudden withdrawal of a great wave from her sides as the hollow of the wave passes along following so quickly its crest—that all these strains are greater than can possibly occur when a ship is borne on such a carriage, and on such a railway, as has been shown to you in this model. Prof. E. A. Fuertes, the Dean of Cornell University, in company with an engineer of high standing, measured the flexure of the steamer *Germanic* in in an, ordinary sea-way, with the extreme points, which were taken for the experiment, only 264 feet apart (while the vessel is at least 400 feet in length). The experiment showed that the central portion of the vessel had an extreme movement, vertically of thirteen inches, or six and a half inches above and below a mean line. There is no doubt that if extreme points on the bow and stern of that steamer had been used there would have been shown a bending flexure in the centre of at least two feet, which goes to prove that a large vessel in a sea-way undergoes strains which would be injurious to her and break her to pieces, were she not specially built to undergo them. She passes through the ocean meeting these fearful strains upon her hull, and yet she comes into port without a leak—sound from stem to stern.

The second objection, that is sometimes raised, is the injury to the bottom of the vessel by lifting her with the cargo on board. An examination of the method of supporting the bottom as shown in this model, will dissipate this objection. It will be seen how much more thoroughly and carefully the vessel is supported than in any lifting or graven dock ever constructed. The vessel as you see is first water borne, as completely as she is in her natural element, on a system of hydraulic columns which hold her up and distribute her weight equally. The broad cushioned surfaces of the supports, their great number and their disposition are such as to make it easy and safe for a vessel to be taken on the railway. The ship after her stormy passage, tossed and buffeted by the waves will lie as restfully in this adjustable system of water columns, as she would at her wharf in a quiet harbor.

A third objection, sometimes heard, is the wind pressure to which the vessel will be subjected. The shape of the vessel, which is shown in this model before you, the broad base upon which she rests, her great width at the bottom as compared with the height, and the side girths which hold her in their embrace, make it apparent that any vessel, that will not be blown over in the water, will remain unmoved on the carriage in which she is imbedded.

There have been many decided expressions of approval given by practical experts on this subject, by men who have designed, built, docked and handled ships in various ways, all to the effect that a vessel can be docked, laden, or she can be moved, laden, on a railway without injury to her. A few of these supporting opinions are here given. "A letter dated February 14th, 1882, from Mr. William S. Buckley, President of the New York Balance Dock Company, gives a list of five ships and six steamers, ranging from about 2,000 to 2,700 tons, that were taken out of his dock with cargoes in them." In this letter Mr. Buckley says:

> "We do not refuse any class of ships or steamers, even with coals and cargoes on board, whose length does not exceed the length of the dock. In every case in which we have taken up steamers with cargoes in, it has been done without the least strain or injury to the vessel. As the rule is to make a charge for raising a cargo on a vessel, they usually come to us without cargo."

The late Edward Hart, U. S. Naval Constructor, in a letter to Mr. Eads, says (quoting a portion, only appertaining to this subject):

> "With a substantial road-bed for your Ship Railway, on the easy grades across Tehuantepec, which I understand do not exceed one or two feet in the hundred, there can be no mechanical difficulty in the way of transporting loaded ships by railroad with entire safety to the vessels, whether they be built of wood or iron."

Mr. Hart was one of the oldest and ablest constructors in the U. S. Navy.

Mr. H. L. Fernald, a constructor of the U. S. Navy of recognized ability and talent stated in a letter as follows:

> "Having carefully examined the plans and papers pertaining to the proposed Ship Railway across the Isthmus of Tehuantepec, I do not hesitate to say that in my judgment there will be no difficulty whatever in transporting in the manner you propose any properly built vessel with absolute safety."

The London *Iron*, of October 3d, 1884, in brief but comprehensive language, sets at rest any fears that may exist in the minds of timorous people in reference to the injury that vessels may sustain by being docked and handled with cargo on board :

> "The question of endangering the structural integrity of a ship loaded with cargo by taking her out of the water and placing her on intermediate supports, is one which has frequently been raised only to be summarily disposed of by those who give the matter a moment's thought. As, however, there is still a popular notion that a loaded vessel under such conditions is subjected to injurious strains, it may be as well if we point out how utterly impossible this is by reason of the construction of the vessel itself. No greater fallacy than this was ever conceived, for there is no form of structure which is known to be subject to more unequal, irregular and ever-varying strains than a ship at sea, and these very points are carefully provided against in her design and construction. A properly designed and constructed ship resembles a girder, and is so built that no matter how she may be tossed about on the waves, the strains, conflicting and almost puzzling as they are, are distributed equally through her framing and plating or planking. If there was any fear of her cargo bursting her sides, as some have held there is, it would have burst them on her first loading, as although water is incompressible in confinement, it is exceedingly yielding when unconfined. Hence the risk of damage to vessels by straining during transport over land, may at once be set aside as puerile, especially in the face of the ingenious arrangement designed by Mr Eads for equalizing their support. Moreover, the raising of ships with their cargoes, from a lower to a higher level, by means of hydraulic lifts has been successfully accomplished for long past. The Victoria Docks, in London, and those at Malta, and Bombay, have been operated for years without an accident. Again it is a matter of common occurrence to keep loaded vessels for days, and even weeks, upon dry-docks for repairs, and then return them to the water without the slightest strain or injury."

The most valuable expert testimony that has been given on this subject is by Sir Edward J. Reed, K. C. B., late Chief Constructor of the British Navy. The testimony was given before the Committee on Commerce of the United States Senate. The following quotations are from his testimony and bear directly on this special subject :

> "I have no hesitancy in saying that the marine ships of to-day are vastly stronger everywhere than they were half a century ago, and that they are now, as a rule, perfectly capable of being docked in dry-docks with their cargoes on board.
>
> "I would like to say first, that there is no fear whatever of a ship undergoing any strain in the process of lifting out of the water (as would be necessary in case of a ship-railway), that she is not liable to at present in ordinary docking.
>
> "I would say further that I am quite sure that the processes of ordinary

docking, as carried on in a vast number of private establishments, are very negligent and insufficient in comparison with those which would be adopted in case of the hydraulic lifts connected with the proposed ship-railway."

In reference to the hydraulic docks at Malta he gives a list of several vessels docked with their cargoes on board, and states:

> "I would call attention to the fact that although ship owners were at first afraid of docking ships in that way with their cargoes on board, they have discovered by the experience of years that no sort of injury does result, for all the ships that are in the Indian Trade now voluntarily employ these docks, and go upon them with their cargoes on board for the purpose of getting their bottoms cleaned and coated on the voyage, instead of having to lie in a more expensive dock in London, for the purpose."

Mr. William Pierce, sole proprietor of the John Elder and Company's Works, Govan, Glasgow, and who built the *Arizona, Elbe, Alaska, Etruria,* and others of the finest steamers afloat says in a letter:

> "I am of the opinion from what I know of the working of iron floating docks that I have designed and built, that iron steamers of 4,000 to 5,000 tons displacement, may be docked, loaded, without any injury whatever."

Commander T. D. Wilson, Chief Constructor of the U. S. Navy, states as follows:

> "I see no good reason why any vessel cannot be successfully raised and transported upon a properly constructed railway, with a grade, as stated, if reasonable skill and care are used in the work, and I believe the strain she will be subjected to will be inferior to those which ocean steamers are constantly exposed to."

Sir John Fowler, a distinguished civil engineer of Great Britain, has himself proposed and designed plans for transporting vessels over land from one level to another, at the First Cataract of the Nile. Mr. Nathaniel Barnaby present Chief Constructor of the British Navy, has stated that the problem of carrying loaded vessels on a railway was not only soluble, but that the solution was fairly indicated in the plans shown him by Mr. Eads. Mr. William John, for some years the scientific adviser of the Committee of Lloyds Register, stated that the lifting of vessels out of the water having become an every day occurrence, the work of placing them on a carriage and transporting them was a simple matter. Mr. George Fosbury Lyster, Engineer in Chief of the Liverpool docks closes a decided opinion on the subject by saying:

> "There will, in my judgment, be little or no difficulty in transporting properly constructed ships from sea to sea with entire convenience and safety."

The firm of Emerson, Murgatroyd and Company, who constructed the great hydraulic docks at Malta and Bombay, agreed with Mr. Eads that they would lift, for the Tehuantepec Ship Railway, loaded ships and place them on a carriage, and then place them on the permanent way, in thirty minutes, agreeing also to build the carriage and locomotives and ten miles of the railway and to guarantee the safe transportation of the loaded vessels over the railway. Messrs. Leader Williams and B. Baker, both prominent Civil Engineers of England, Professor Elgar, General Manager of Earl's Ship Building and Engineering Company, and Mr. Martell of Lloyds, have given strong testimony to the entire practicability of a ship railway.

After canvassing this whole subject of the practicability of a ship railway the Senate Committee of the United States Congress summed up the evidence as follows:

> "The testimony upon the subject is so over-whelming and conclusive in its character that the Committee has no hesitation in reporting that the construction of a ship railway and its successful operation are entirely practicable."

Within the last two months and a half this working model of a ship railway has been shown to at least ten thousand people in New York, Pittsburg and Washington, many of whom were practical experts in building and handling vessels.

The general opinion as far as I know, without an exception, has been in favor of the practicability of taking vessels overland from ocean to ocean. The objections which many practical men have in their minds are met by the very simple and yet very complete appliances shown in this working model.

THE ROUTE.

As is shown on the map of the world the location for the ship railway is at the Isthmus of Tehuantepec in Mexico, north of, or rather west of, the Promontory of Yucatan. The length of the railway is 134 miles between the terminal points. The country along the route is naturally divided into three divisions,—the Atlantic, Central and Pacific Divisions. The water shed on the Atlantic or North Side is drained by the Coatzacoalcos River. At the mouth of this river is a bar formed by sedimentary deposits, over which there is a least depth, at present, of fifteen feet. This bar can be easily and economically removed by the means of jetties, concentrating the river current like those at the mouth of the Mississippi River. Inside the bar is a wide and deep anchorage, large enough for all the inter-oceanic commerce. The river for twenty-five miles to Minatitlan is broad and deep, and except at one or two points will carry a good twenty-six foot channel. At Minatitlan the railway commences, the terminal dock being in a bend of the river where there is from thirty to forty feet of water. By locating the terminus at this point the marshes and swampy grounds which exist in the lower region of the Coatzacoalcos River, are avoided and the railway starts on high and hard ground. A gentle ascent extends from Minatitlan to the central division, through a country partly wooded and across rolling prairies. In the Central Division the line passes through a series, or succession, of valleys, bordered on each side by mountains and hills, spurs of the main Cordilleras. The line passes across the level plain of Tarifa and through the Tarifa Pass, which is the lowest pass on the Isthmus. The highest point of the route is 726 feet above the mean level of the ocean. From the Tarifa Pass to the Pacific Plains the line follows a succession of narrow valleys along the beds of the mountain streams, and reaches the plains by a continuous grade of one per cent. or $52\frac{8}{10}$ feet per mile. This is the only one per cent. grade on the whole line, the others being considerably less and most of the line being practically level. Across the Pacific Plains there are no obstructions, the ground being of hard, sandy material extending to the Pacific. The terminus on the Pacific side will be on one of the lakes or lagoons, shown on the topographical map. At the natural outlet of the lower lake, at Boca Barra, the deep water of the ocean approaches very near the shore line so that jetties 3,000 feet long will reach 36 feet depth of water. Some dredging to make a deep channel through the lagoon will be necessary and a harbor inside the jetties will be excavated where there is now from 18 to 24 feet depth of water. Building materials of the best kind of timber and stone are available along the line of the railway. The climate is exceptionally good. A party of engineers, nearly all of whom were unacclimated, were sent to the Isthmus in March, and were able to work through the rainy season without sickness. The Isthmus is inhabited, especially on the Pacific Side and in the Central Division, by a hardy, industrious, agricultural Indian population. Careful estimates made of the number that can be obtained for the construction of a ship railway show that ten thousand at least will be available for that purpose.

I have no hesitation in saying that it is entirely practicable to build and maintain a railway that will carry the loads that will be imposed upon it. More than that I will say that the engineering difficulties and obstacles met with in the construction of the New York, West Shore and Buffalo Railway, between New York and Buffalo, just completed, were much greater than they can possibly be on the Tehuantepec Ship Railway. The construction of the New York terminal, in soft mud, over one hundred feet in depth, the steep river slopes on the Hudson River, which required peculiar constructions, the sliding materials met with at several points on the route, the cutting into the clay hillsides along the Erie Canal and the construction of the immense retaining walls necessary for long distances required much more skill, and I might say, much more money, than will be required in fully completing and equipping a ship railway across the Isthmus of Tehuantepec.

ADVANTAGES OF THE ROUTE AND THE METHOD OF TRANSPORTATION.

In alluding to other projected routes for inter-oceanic transit, and other means of accomplishing that transit, it is not intended to depreciate them, or to show that they are constructively impracticable, but simply for the purpose of showing the reason for the inception of the project for a ship railway. The *advantages* of the Tehuantepec route, and of the ship railway, were of course the prime cause of the inception of this project discussed to-night. The great detour required by commerce to cross the Isthmus at other points, and the immense cost of constructing the proposed ship canals led to the belief that the transportation of ships overland was the final and only solution of this great problem which had for centuries absorbed the attention of commercial men and engineers.

A glance at this map of the world will show at once, without giving any figures, the immense advantages in distance that the Tehuantepec route has over the Panama or the Nicaraugua routes. The distance in an air line from the Tehuantepec Ship Railway line to that of the Panama Canal is over 1200 miles, a distance hardly appreciable until we compare it with some well known distance with which we are familiar. This distance if stretched to the westward in a straight line from New York, would reach 50 miles west of Omaha; or if southward from

New York it would reach the centre of the Florida Straits. In other words, the Tehuantepec route is that much nearer to the United States than the Panama Canal. When we consider also that vessels making the voyage from Boston, New York, Philadelphia or any Atlantic ports, but particularly from the Gulf ports, must partially double the distance in order to reach San Francisco and other Pacific ports (Honolulu or Yokohama or any of the ports lying in that direction), we can see what an immense saving of distance there will be by the Tehuantepec route. The two great points to unite by the shortest possible line for the United States are San Francisco and New York or other points lying near these two. The nearer the route can be to a straight line drawn between these two points, the greater is the saving in distance and this is what an inter-oceanic communication is intended to accomplish. From a table before me giving the distance by several routes on certain main commercial lines of the world, furnished by the Superintendent of the United States Coast and Geodetic Survey, you will see the immense saving of distance by the route proposed, over the present sailing and steamer routes by Cape Horn; Cape of Good Hope, Suez Canal and the Panama Railroad, or Canal.

If the saving in distance by the Tehauntepec route on 18 principal lines of commerce is summed up, we have a total of 125,000 miles, equal to five times the circumference of the earth. The distance saved by the Tehuantepec route over the present Cape Horn route between San Francisco and Liverpool, is about 8,000 miles, equal to the diameter of the earth, and saving in time about two and a half months to a sailing vessel. The distance saved between San Francisco and Boston, New York and Philadelphia is about the same. When the magnitude of this saving of distance is taken into account, the immense benefits to arise from these shortened lines of commerce, will be appreciated by every one.

As Commodore Shufeldt said in 1871, in an official report of his survey of the Isthmus of Tehuantepec, "each Isthmus rises into importance as it lies nearer to the centre of American commercial interests; any intrinsic value of this eminently national work ought to be based upon the inverse ratio of the distance from that centre." An all-water route by way of Tehuantepec connects the east and west coast lines of the United States and Mexico, and as has been stated, renders our own territory circumnavigable, as it were.

Table of Comparative Distances in Statute Miles.

	Total Distance. Miles.	Excess over Tehuantepec route. Miles.
FROM NEW YORK TO HONG KONG.		
Via Cape Horn	20,379	8,777
Cape of Good Hope	16,945	5,343
Suez Canal	13,596	1,994
Panama R. R	12,953	1,351
Isthmus of Tehuantepec	11,602	....
NEW YORK TO AUCKLAND, N. Z.		
Via Suez Canal	16,871	7,447
Cape of Good Hope	16,719	7,295
Cape Horn	13,890	4,466
Panama R. R	10,305	881
Isthmus of Tehuantepec	9,424	....
NEW YORK TO MELBOURNE.		
Via Cape Horn	15,215	4,150
Suez Canal	15,171	4,106
Cape of Good Hope	15,019	3,954
Panama R. R	11,826	761
Isthmus of Tehuantepec	11,065	....
NEW YORK TO SAN FRANCISCO.		
Via Cape Horn	15,687	10,797
Panama R. R	6,063	1,173
Isthmus of Tehuantepec	4,890	....
LIVERPOOL TO YOKOHAMA.		
Via Cape Horn	19,400	5,945
Cape of Good Hope	17,653	4,198
Panama R. R	14,540	1,085
Isthmus of Tehuantepec	13,455	....
LIVERPOOL TO AUCKLAND, N. Z.		
Via Cape of Good Hope	16,221	3,412
Suez Canal	14,645	1,836
Cape Horn	13,897	1,088
Panama R. R	13,312	563
Isthmus of Tehuantepec	12,809	....

Table of Comparative Distances in Statute Miles.—Continued.

	Total Distance. Miles.	Excess over Tehuantepec route. Miles.
LIVERPOOL TO SAN FRANCISCO.		
Via Cape Horn	15,803	7,527
Panama R. R.	8,885	609
Isthmus of Tehuantepec	8,276	....
NEW ORLEANS TO HONG KONG.		
Via Cape Horn	20,804	10,531
Cape of Good Hope	17,485	7,212
Suez Canal	15,108	4,835
Panama R. R	12,308	2,035
Isthmus of Tehuantepec	10,273	....
NEW ORLEANS TO MELBOURNE.		
Via Suez Canal	16,683	6,947
Cape Horn	15,640	5,904
Cape of Good Hope	15,560	5,842
Panama R. R.	11,181	1,445
Isthmus of Tehuantepec	9,736	....
NEW ORLEANS TO SAN FRANCISCO.		
Via Cape Horn	16,112	12,551
Panama R. R.	5,418	1,857
Isthmus of Tehuantepec	3,561	....

There is another immense advantage which the Tehuantepec route has over that of Panama, in fact over any other, namely, the advantage of winds and currents which are always favorable for sailing vessels on either side of the Tehuantepec Isthmus, and always unfavorable for them on either side of the Darien Isthmus. Every navigator will testify to the correctness of this statement. I would refer here to Commander Selfridge, of the United States Navy, who has explained the matter in an official report. The reasons for this difference in winds and currents are: The peculiar configuration of the islands lying to the east of the Carribean Sea and the great altitude of most of them compel the trade winds coming from the northeast, as they approach to rise into the upper air, so that they do not reach the Isthmus at Darien. The Andes and the Cordilleras carry these winds still higher, and make a region of perpetual calms in the Pacific Ocean west of the Darien Isthmus—or rather of "doldrums" as they are called, for the conditions are "calms, squalls, light baffling winds and storms of wind and rain." At Tehuantepec the northeast trades reach down to it and pass through the low depressions into the Pacific Ocean. The former harbor of Tehuantepec on the Pacific side was called "Ventosa," which means "windy." But by far the strongest statement, and the most convincing, because of its high authority, is that of Lieutenant Maury, the great geographer, who in eloquent language thus describes the Gulf of Mexico and its commercial resources:

> "From the Gulf of Mexico, the great commercial markets of the world are down hill. A vessel bound from that Gulf to Europe places herself in the current of the Gulf Stream, and drifts along with it at the rate, for part of the way, of eighty or one hundred miles a day. And when there shall be established a commercial thoroughfare across the Isthmus, the trade winds of the Pacific will place China, India, New Holland and all the islands of that ocean down hill from this sea of ours. In that case, Europe must pass by our very doors on the great highway to the markets both of the East and West Indies. This beautiful Mesopotamian sea is in a position to occupy the summit level of navigation and to become the great commercial receptacle of the world. Our rivers run into it, and float down with their currents the surplus articles of merchandise that are produced upon their banks. Arrived with them upon the bosom of this grand marine basin, there are the currents of the sea and the winds of heaven, so arranged by nature that they drift it and waft it down hill and down stream to the great market-places of the world. Never was there such a concentration upon any sea, of commercial resources; never was there a sea known with such a back count y tributary to it."

The conditions that we have given in reference to the winds and currents, are very important to American commerce. It has been stated that sailing ships are giving way rapidly to steamships; but from the late report of Mr. Jarvis Patten, the United States Commission of Navigation, we are disposed to believe that the sailing ship still holds its own; for he gives the total number of sea-going sailing ships owned by citizens of the United States, as 6,214, with a tonnage of 2,099,218, while there are but 422 steamships, with a tonnage of 601,186. Another very important statement made by him is this: That we in this country with our excellent woods, which can be obtained at reasonable prices, can build sailing ships at from $50 to $55 per ton; but that it costs us to build iron sailing ships from $65 to $75 per ton. On the other hand, it costs in England to build wooden sailing ships $75 to $80 per ton; but they can build iron ships at from $50 to $60 per ton. It is therefore very important for our American commerce, and our merchant marine, that the interoceanic route should be located where it can be used to advantage by our sailing ships. The importance of this will be appreciated by every commercial man along the Atlantic and Pacific coast, for we are still building these fine wooden sailing ships for the San Francisco trade, and for other sea-going commerce.

I will state further in reference to the Panama Canal now being undertaken by the French, that the immense cost, probably not less than $250,000,000, the great length of time required for its construction, the cost of maintenance where the bed of the canal is so far below the torrential streams and the clayey slopes of the excavations, one of them 500 feet in height, exposed to the exceptional rain fall of the topics, render it economically impracticable.

In reference to the Nicaragua route, certain very grave objections and obstacles exist. Its great length, 186 miles, the locks necessary for vessels to pass through, from 12 to 20 in number, the time required for passing through the canal, (not less than four days), the ruined harbor at Grey Town which will require probably $14,000,000 to restore, its immense cost, which by the estimate of Major McFarland, of the United States Army Engineers, is $140,000,000 based on labor at $1 only per day, or that of Captain Bedford Pim, of the British Navy, who states that it will cost $200,000,000; the obligations to which we commit ourselves that will entangle us with England, with Nicaragua itself, and with the adjacent Central American States; the purchase of a strip of land in a foreign country; the loan to be made to the State of Nicaragua of several millions of dollars; the guarantee to defend the canal; the powerless condition of our navy at present, to comply with any such agreement—all these render it inadvisable to enter upon such a work. If this country wishes to control an interoceanic crossing, and to be able to defend it, let it adopt a route that is capable of defense. At Tehauntepec, with a favorable treaty with the Government of Mexico, and by means of railway lines that are being extended from the United States to the Mexican Capital and beyond even to Tehuantepec with money furnished by our citizens, a land force of 100,000 men could be quickly transported from the Pacific Coast, the Mississippi Valley and the Atlantic Coast to meet an invading force. The Gulf of Mexico (if we have a navy that can do any defensive work) can be easily protected, as the only two outlets from it to the ocean are, one at the Florida Straits, and the other between Yucatan and Cuba. This route is vastly superior to any other as a strategic point. Mexico is a sister republic, bound to us with ties that are growing stronger and stronger with every dollar of American money that is spent on her soil, in building her railroads and other constructions for the development of that country. She has a population of 12,000,000. Free at last from the harassing complications which invasions of her soil by foreigners and over turning of her legitimate Governments have brought upon her, she has become a strong republic, well advanced in agricultural, industrial and commercial pursuits, and a powerful ally of the United States.

There have been constructed within the last two or three years in Mexico 2,525 miles of railroad, at an expense of $60,000,000, two-thirds of which have been furnished by citizens of the United States. Her imports have increased from $5,000,000 to $10,000,000 in the last six years, and her exports from $6,000,000 to $12,000,00; and her revenues have doubled within four years.

There are four main longitudinal trunk lines of railroad building and in course of construction, from the American border. With great liberality she has subsidized these railroads and assisted in every possible way the development of her resources by means of railways and other improvements. She has given to Mr. Eads as projector of the Tehuantepec Ship Railway a valuable concession, which, while it brings with it no subsidy, gives certain other advantages which are of much greater importance. The present status of the ship railway enterprise is briefly given by saying that a company has been formed during the last two years, which owns the concession and which has furnished the necessary means for the preliminary expenses, making the surveys and plans and performing other work necessary to bring the project before capitalists. Important steps are now being taken, and if the object in view is reached, it will be but a short time before the plans will be carried into execution; and instead of seeing by the imagination of an artist, a ship moving among the palms of the tropics, as you have seen on the canvass to night by the lantern slides kindly furnished by your Secretary, you will be permitted to witness it in person on the Isthmus of Tehuantepec.

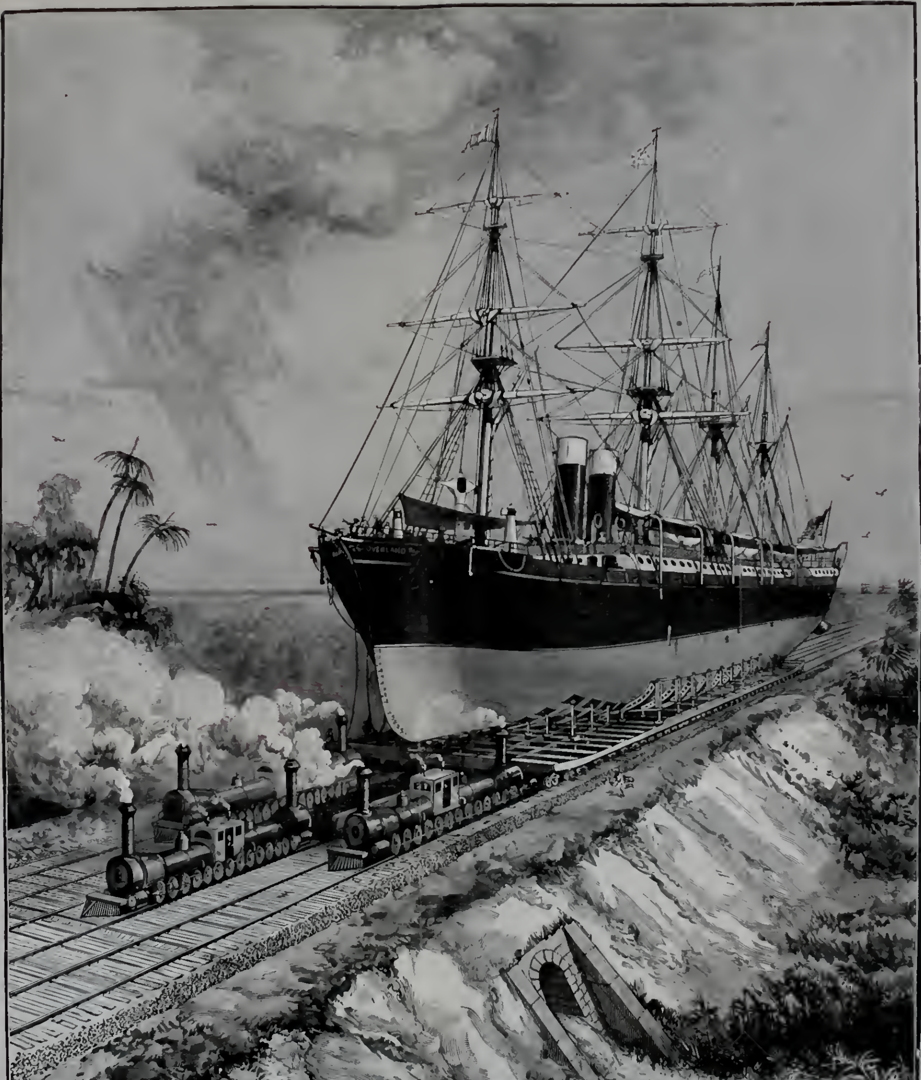
COMMERCIAL RESULTS.

The question often asked is, "Will it pay?" It is necessary to satisfy capitalists on this point before they are willing to put their means into an enterprise of this magnitude, which according to estimates from actual surveys, will entail an expenditure of about $50,000,000. To those who are so inclined, a study of the details relating to the commerce which may be expected over the ship railway by the year 1889, when it may possibly be completed, will prove conclusively that at least 6,000,000 tons can be counted upon as certain, probably more, and that as the years go on and as commerce increases and is drawn more and more to this route, a larger amount still may be anticipated. The Suez Canal can be used as a precedent in this matter. That has now reached the amount of 6,000,000 tons as was anticipated by Mr. De Lesseps when the work was first commenced. 10,000,000 tons is expected in 1888. The revenue for the year 1883 was $13,702,413. The dividend for 1882 was 17 per cent. The dividend expected in 1890 is 30 *per cent.* The location of the American Isthmus in reference to commerce and the varied necessities which the opening of an all water route will meet, promise certainly a business fully equal to that of the Suez Canal.

These are the results to the commerce, of not only this country but the world. These are also the important results to industrial pursuits and through them to the welfare of the nations. But still a greater result will be accomplished. With the Suez Canal and the Tehuantepec Ship Railway opened, not only commerce, but Christianity also will girdle the world. The last barrier will be broken down. Heathendom will be brought to the door of Christianity and to the feet of the Great Teacher. China, Japan, Hindoostan and the Islands of of the Pacific, to New York and Philadelphia. This object is more worthy of our steadfast and determined purpose to build the ship railway than all others

The far Pacific countries will then be near neighbors to Massachusetts Bay, Sandy Hook, the Delaware, the Chesapeake, the Mississippi River and Galveston Bay.

Therefore, in conclusion, we say to capitalists, give us of your means; to men of commerce and trade and manufactures, give us your co-operation; to men of science and of civil and mechanical engineering constructions, give us your help and suggestions; to men devoted to



THE INTEROCEANIC SHIP RAILWAY.—A STEAMER IN TRANSIT.

spread of morals and religion, give us your sympathy and your God speed in the great task before us; desiring you all to understand, that, confident in the immutable laws of Nature, we are therefore, confident of success; and are determined to achieve it.

[Referring to Plate I of detailed illustrations, Fig. 1 shows the process of running down the adjusting nut of the supports to a bearing on the plates of the cross girders. The details of the support are shown in Fig. 4, with the hydraulic ram forcing it up to its position under the vesssel. *A*, is the rod with the thread cut in it; *B*, the adjusting nut; *C*, the girder; *D*, the ram.

Fig. 2, Cross-section of the pontoon, towers and carriage. *A*, is a side support; *E*, *G*, *F*, the adjustable hinged girth; *D*, the ram; *LL*, the towers for the pressure pumps which are on the top of the towers; *I*, is the pipe through which the water is withdrawn from the pontoon by the centrifugal pump; *J*, is the reservoir from which the water is taken to force a pressure through the pipes to the rams; *K*, is one of the cylinders for the hydraulic governors.

Fig. 3, shows a part of the deck of the pontoon with the rails and the lines of rams projecting above the deck.

Plate II is a perspective view of the pontoon and railway cradle.

Plate III exhibits perspective view, plan and sectional elevation of the floating turn-table.

Plate IV is a view of a steamer in transit.

Plate V exhibits Tehuantepec as the centre of the world's commerce.]

POLAR SPOTS UPON VENUS.—Trouvelot confirms the measurements of Bouquet de la Grye and Arago on the photographs of the Venus transit. Since his first recognition of the polar spots in 1877, the southern has always appeared more visible and more brilliant than the northern, and towards the end of January, 1878, a short time before the inferior conjunction of Venus, the southern spot often looked as if it was composed of numerous very brilliant peaks, which were outlined in profile on the sky. On many of the photographs of the transits of 1874 and 1882 there is a curious swelling in the luminous aureole which surrounds the planet. It would be interesting to ascertain whether this swelling corresponds with the position of the polar spots at those periods.—*Comptes Rendus*, June 16, 1884. C.

CONTOUR OF VENUS.—Messrs. Bouquet de la Grye and Arago have communicated to the French Academy some interesting results obtained by examining photographic plates of the transit of Venus. The principal object of their measurements was to determine the distance between the stellar and planetary centres upon each plate in order to calculate the solar parallax. For his purpose they made microscopic observations of the contour of each disc and found a protuberance amounting to 116 kilometres (72·08 miles). There are four other manifestations of protuberances which are of less magnitude.—*Comptes Rendus*, June 9, 1884. C.

FAC-SIMILE TELEGRAPHY.*

By Prof. Edwin J. Houston.

A system of fac-simile telegraphy includes the means whereby handwriting, pen sketches, outlines, hieroglyphics, etc., produced at one end of a telegraph line, are automatically reproduced at the other end. A system of fac-simile transmission comprises a transmitting and a receiving apparatus. This apparatus consists, for the greater part, of similar surfaces maintained in almost synchronous motion. The message is written on one of these surfaces, and received automatically on the other, where it is reproduced.

The means whereby the messages can be transmitted and reproduced, may be divided into two general classes, viz., In one of these classes a series of electrical impulses, interrupted or completed at periods dependent on the nature of the message to be sent, are transmitted by means of an apparatus at one end of the line, and reproduced at corresponding points on a similar apparatus at the other end.

In the other class, a stylus or pen, moved by the hand, while under the influence of an electro-magnetic field, sends an induced electrical impulse over the line, which causes similar movements at the other end of the line.

Fac-simile telegraphy is by no means a thing of to-day. It is an old invention. As early as 1843, Bain invented a device which he called a method of "taking copies of surfaces," such for instance as printer's type, etc., at a distance, by means of similar instruments placed at the extremities of a telegraph line, and maintained in as nearly synchronous motion as possible.

In 1850, Bakewell, of London, invented a device for transmitting autographic messages. This consisted of two entirely similar cylinders driven at a uniform speed by clockwork, and maintained at an approximately uniform synchronism by means of breaks operated at small periodical and adjustable intervals by the action of a local battery and pendulum.

In 1852, Hunter made improvements in fac-simile telegraphy. These improvements related mainly to the preparation of the copy to be transmitted.

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* Substance of remarks at the Stated Meeting of the Franklin Institute, held Wednesday, March 18, 1885.

In 1855, Jones made certain improvements in fac-simile telegraphy by means of which "characters formed at one station are reproduced at another distant station by the agency of electricity." "The transmitting instrument consists of two frames or boxes placed at right angles with each other," each of which incloses a set of cog-wheels with a communicating apparatus. A pencil lever holding a pencil is connected by rods and universal joints to each of the cogwheels so that the axes indicate the movements of the pencil, fixed to the lever, by transmitting and breaking currents of electricity. This, it will be seen, was a device by which the motion of the pen at one end is reproduced at the other. The instruments were so arranged that the making and breaking of the currents produced fac-simile movements of the pencils in the reproducing apparatus.

In 1858, Caselli, an Italian, devised a plan whereby fac-similes of handwriting and drawings were transmitted by electricity with greater rapidity than by any other method then devised. The means were as follows: The motive power was an ordinary clockwork; the rotation of the cylinder was not continuous, but intermittent, the necessary regulation being obtained by means of a pendulum driven by electro-magnetism. Caselli styled his apparatus the "pantellegraph," and constructed it so as to receive and transmit at the same time. The greatest rapidity he attained was, I believe, one square inch of surface covered in a minute.

In 1856, Thurrell, Müller, and Chidley, jointly invented certain improvements in transmitting fac-simile copies of writings and drawings by means of electric currents. In this form of apparatus a magnetized point or roller was caused to move to and fro over the surface of the transmitting cylinder. As long as the magnetizing current was passed, the point would trace on the cylinder a continuous line, but as soon as there was a break in the current the point was drawn away by a spring. As in the previous devices the message or despatch, written in some non-conducting ink, caused a break in the current whenever the conducting point passed over it. On the cessation of the current the magnetized point, moving over the receiving cylinder, was drawn away from the magnet and a break made in the continuity of the line it was producing. The successive breaks so obtained reproduced on the receiving cylinder the design traced on the transmitter.

Myers invented an autographic telegraph for the production of fac-simile copies of handwriting, which does away with the chemically prepared paper ordinarily employed. In nearly all fac-simile telegraphs, the electrical current is caused to trace a line by means of chemical decomposition as it passes over the surface of the cylinder. When it passes over the chemically prepared paper it causes a decomposition of the material in which the paper has been steeped or soaked. In the apparatus of Myers, he does not produce his writing in this way, but employs in its place markings or tracings produced by a marking point worked by an electro-magnet.

Lenoirs invented an autographic telegraph something similar to that employed by Bakewell. The record, however, instead of being made by chemical action was produced by an electrically controlled magnetic device.

W. E. Sawyer invented an automatic telegraph which was an ingenious device. The message was written with ordinary ink on any stiff paper, dusted with powdered shellac and then transferred by powerful pressure to a zinc plate.

Bonnelli's autographic telegraph consists in a device by which the message set up in ordinary type at one end of a telegraphic line, is reproduced at the other end on a sort of chemically prepared paper by means of makes and breaks that take place as the conducting wires are drawn over the surface of the type.

Edison exhibited at the International Electrical Exhibition of Philadelphia an automatic telegraph for fac-simile transmission of despatches in Roman letters. This apparatus was similar to Bonnelli's in the fact that the message was transmitted in Roman letters. They differed, however, in that whereas the former set up or prepared its message for transmission in type, Edison, by an ingenious device, stamped the message in a fillet of paper. He had a series of punches which were grouped together like the keys of a piano, on which the letters and figures were marked. If he pressed his finger on one key, a certain group of punches would instantly cut in the paper fillet a series of equally grouped circular holes, so that the letter would be cut in the paper in a series of holes something like a stencil. When, therefore, the conducting points were drawn over the cylinder, as they pass over the perforations they drop down and complete the circuit on a metallic cylinder on which the paper rests and so produce similar marks on the cylinder at the other end. Edison also exhibited an autographic telegraph for fac-simile transmission.

As regards the details of Mr. Delany's system of fac-simile transmission, I wish to say that I am in somewhat of a quandary in regard to this evening. I was invited to make remarks on the Delany Fac-simile Telegraph, some days after the announcement was put on the card. I do not at this time intend to explain the details of this system, since Mr. Delany, for reasons which will be understood by every inventor here, does not wish me to disclose them. I have, however, some messages sent by this system over a single telegraph wire, which I will afford you an opportunity for examining.

You are all doubtless aware of the fact that Mr. Delany, by the invention of his system of synchronous-multiplex transmission, has been singularly fortunate in obtaining what others tried in vain to obtain, viz., almost absolutely perfect synchronism. He has been able to maintain the uniform rotary motion of two cylinders, and to keep them running in accord with one another for months, although thousands of miles apart, without a variation of the one-hundredth part of an inch in their movements.

Mr. Delany's system of multiplex transmission is not a matter which is simply down on paper, but is being carried on every day on commercially established telegraph lines.

You will readily understand from what I have said of other systems of fac-simile transmission, that the synchronous-multiplex system might be expected to place in the hands of the community a means of obtaining fac-simile messages at a rate of speed and with a degree of certainty to which none of the other systems could hope to attain.

None of them pretended to that kind of synchronism which Mr. Delany has established; they nearly all went for a moment and stopped, and then went on again after a fresh impulse.

With some crudely prepared apparatus, Mr. Delany has been able to transmit the despatches which I now show to you, both as actually received and as projected from their photographs on the screen.

From the earliest time, even from that of Bain, when the idea of fac-simile transmission was first brought before the public, it has been recognized how great an addition would be afforded to the practical working of the telegraph if fac-simile transmissions could be given with sufficient speed and certainty. It will readily be seen from the brief history I have given, that considerable effort has already been put forth by ingenious men in this direction.

Two difficulties have heretofore stood in the way of successful fac-simile transmission; one was that it was slow, another that it was by by no means certain, since much depended upon the apparatus being kept in perfect synchronism. When I had the pleasure of reading a paper on multiplex-synchronous telegraphy, I remarked that nearly all electricians agreed that when synchronism was absolutely obtained, almost anything requiring mere mechanical accuracy was possible in telegraphy. Fac-simile transmission is one of these. The advantages of a perfected commercial system of fac-simile transmission are manifold; among them are the following; viz., the portrait of a criminal can readily be reproduced and flashed across the wire all over the country. Important autographic despatches may be sent. I have here a despatch to Dr. Wahl, written in a handwriting which can be readily distinguished, and which has been sent over this telegraph:

"DR. WILLIAM H. WAHL,
Secretary Franklin Institute.

"NEW YORK, March 13, 1885.

"Please send me twenty copies report Examiners, Section XVIII.

"P. B. DELANY."

So it would be quite possible to flash over the wires, and send to the newspapers, rough pen-and-ink sketches of any scene of disaster which should occur, along with the telegraphic description of the disaster. I could not help thinking, while Mr. Ives was reading his very interesting paper on "Isochromatic Photography," that I would have liked to have had him make photographs of the messages I have shown you, as the originals are blue prints, and it is difficult to obtain a good photograph from a blue print.

The greatest rate of transmission which he has obtained by the aid of the exceedingly crude apparatus, which will give, perhaps, but a third or a fourth of the rapidity of the perfected apparatus, is twelve square inches a minute.

In response to a question from the President, Prof. Houston said the perfected apparatus would probably cover from thirty-six to forty-eight square inches per minute.

OBSERVATIONS OF SOLAR PROTUBERANCES.—In his report of the observations at the Royal Observatory of the Roman College during the year 1883, Tacchini gives indications of epochs of double maxima as well as epochs of single maxima in the solar protuberances of each hemisphere, and he judges from analogy that the irregularities in the apparent contour of Venus may be due to a gaseous condition in that planet.—*Comptes Rendus*, July 15, 1884. C.

Book Notices

The Civil Engineer's Pocket-Book, of Mensuration, Trigonometry, Surveying, Hydraulics, Instruments and their Adjustments, Strength of Materials, Masonry, Principles of Wooden and Iron Roof and Bridge Trusses, Stone Bridges and Culverts, Trestles, Pillars, Suspension Bridges, Dams, Railroads, Turnouts, Turning Platforms, Water Stations, Cost of Earthwork, Foundations, Retaining Walls, etc. In addition to which the Elucidation of certain Important modes of Construction is made in a more simple manner than heretofore. By John C. Trautwine, C. E., etc. Copiously illustrated (22d thousand). Revised, corrected and enlarged. By John C. Trautwine, Jr., C. E. New York: John Wiley & Sons, 15 Astor Place. London: E. & F. N. Spon, 1885.

In making a careful comparison between the last (the 22d) edition, and the one that precedes it, the expert cannot fail to be struck with the great improvement exhibited by the present edition. We say improvement, although it seemed almost impossible that the book in its various editions needed any other than, perhaps, such as related to minor details only, and such additions as were needed from time to time in bringing the book down to date. The value of Mr. Trautwine's book has best proved itself by the fact that perhaps seventy-five per cent. of all of those who have occasion to use such a work of reference, prefer it to-day to any other. This is no doubt directly due to the practical and common-sense manner in which Mr. Trautwine treats the subject-matter. A. S.

A Handbook on the Teeth of Gears, their Curves, Properties and Practical Construction; with Odontographs for both Epicycloidal and Involute Teeth, Rules for the Strength of Teeth, a Table of Pitch Diameters, and much other General Information. By George B. Grant. Published by the Author, 66 Beverly street, Boston, N. D.

This little work gives, in a clear and concise manner, the forms of gear teeth, their mode of construction, their strength, the curves in use, and the manner of laying out the teeth by the use of Willis' Odontograph, as well as by the improved Willis and Robinson. Tables of pitches, pitch diameters and clearances, are also given. Illustrations and examples accompany the explanations, thus materially assisting the student in designing teeth for any purpose. W. B. L.

Steam Making, or Boiler Practice. By Charles A. Smith, C. E., etc. Chicago: The American Engineer, 182–184 Dearborn street, 1885.

It has been a subject of surprise as well as regret that, in this land of steam boilers, the literature of the subject should be so very disappointing. This is, no doubt, due to the fact that nearly all such works are the productions of men without any practical experience. The result is that we get only a rehash of old books, reports and trade circulars.

What is wanted in a work of this kind, is, that it should contain practical notes on the designing and arrangement of riveted joints, tracing, spacing (both of flues and rivets), and, last but not least, on the best arrangement for the combustion of the gases, both for internally and externally fired boilers.

Mr. Smith's book certainly cannot be said to supply the want. Out of the fifty-three different types of boilers, only two examples of horizontal flue (tube) are shown, whereas this style of boiler is the most common in use in this country.

The author states in the second paragraph of the preface that "in such a work there can be little originality," and that he is indebted to many sources for his information. This will be news, indeed, to the engineer.

The work is arranged in chapters, on the nature of heat, properties of steam, combustion, externally and internally fired boilers (the latter including portable, locomotive and marine), and on the subjects of design, construction and fittings.

These are all proper in their place, but the information that is wanted in a work of this kind, as, for example, the determination of the best pitch and diameter of rivets for a given thickness of plates, and form of joints, is lacking. It is a well-established fact that, as the majority of our boilers are now constructed, the strength of the plates per square inch of section is usually less, to begin with, than that of the rivet; the plates commonly used are liable also to reduction by punching, etc.; while the section of the plate itself is liable also to be reduced by corrosion. It is advisable, therefore, that riveted joints should have an excess of plate section—exactly the reverse of present practice.

This is a point in boiler construction and practice which the author has not touched on at all, and, in view of the present rapidly extending use of high steam pressures, is the most important question in boiler construction.

The part referring to boiler setting, especially for externally fired boilers, considering the fact that this kind of boiler is more largely used in this country than any other, is very scant both in information and illustration.

As a book of reference for what has been done in the past with such boilers as are now in use, it will be found convenient. W. B. L.

THE FALLACY OF THE PRESENT THEORY OF SOUND. By Henry A. Mott, Jr., Ph.D. New York: Printed for the author, by John Wiley & Sons.

In 1877, a Methodist minister, Rev. A. Wilford Hall, published a book entitled "The Problem of Human Life, Here and Hereafter," in which he made an elaborate attempt to prove that several of the generally accepted theories of modern science are devoid of foundation. Among these he included the wave theory of sound. His book seems to have attained some notoriety, chiefly among uneducated people, but is unknown to most physicists. The author claimed to have made some original discoveries in sound, but did not publish them in any scientific journal of recognized standing. He indulged in the most pointed abuse of Professors Helmholtz, Tyndall, and Mayer for refusing to notice him, and offered a large reward in money to any one who could prove his theories false, but without defining any standard by which the wager would be won or lost.

Dr. Henry A. Mott has become convinced that Dr. Hall is not properly appreciated. Being a member of the New York Academy of Sciences, he presented before that body, in December last, a paper on Sound which forms the greater part of the present volume. He is thoroughly of opinion that the wave theory is false, but he makes no attempt to substitute any other theory. He states in the preface that what he does is "a very bold undertaking" but he has less boldness than his master, who promulgates a theory of his own, that sound is due to emanations of an *immaterial substance.* The master attempts to be constructive; the disciple is only abusively critical, but on his last page briefly promises to give a better theory at some future time. Many of the arguments employed by him are taken directly from Hall's book. To such an extent is this true that any one who reads Hall's chapters on Sound finds in them the destruction of most of the claims to originality that Dr. Mott might otherwise make for himself. He shows some skill in the arrangement of his topics, but very little comprehension of the fundamental conceptions underlying the wave theory, which he thinks has suffered "complete annihilation" at the hands of himself and Hall. It is but fair to add that he gives Hall due credit, by numerous citations.

To outline any considerable number of the objections advanced by Dr. Mott would carry us far beyond the limits of a book notice. He is particularly abusive of Professor Tyndall (p. 25), calling one of his illustrations (Tyndall on Sound, p. 42) "a most childish experiment," and showing how a simple device would have "destroyed the experiment altogether." He exhibits either no conception or a very vague conception (p. 17) of Fourier's Theorem. He agrees with Hall in confounding velocity of wave propagation with velocity of periodic motion (p. 23), and concludes that "if there was the least truth in the wave theory, the sound of a church organ should get up a cyclone which would blow a cathedral into atoms." He holds up to view what he believes to be the falsity of the usual methods of illustrating interference of sound, thinks that beats are in no way due to air waves, and sustains Hall's view that such operation "takes place in the instruments themselves or in their potential and practical sympathetic attraction for each other, without regard to the coincidence or interference of such useless nonentities as these so-called atmospheric condensations and rarefactions" (p. 91). Such sympathy is evidently very "potential and practical." He then cites a remarkable experiment in confirmation of this view, "Suppose, for example, two forks mounted upon their resonant cases and tuned sufficiently out of unison to produce, say, one beat to the second. If sounded in close proximity to each other or in a position of strong sympathetic attraction, a listener a hundred feet away from them will distinctly hear their beats; will, in fact, hear them as far away as the sound of the forks is audible. But let the two forks while sounding be quietly separated only a few feet toward the right and left of the listener, and although he will continue to hear their united sounds in full force, yet the beats will entirely cease, showing that they result from the sympathetic influence of the two forks upon each other owing to their affinity."

Dr. Mott deserves credit for the discovery of mechanical "affinity." If an impatient reader should call such science the product of simplicity or ignorance, the experiment just described is not hard to make. The author is imaginative, if not confiding. Words are sometimes more charming than facts.

Dr. Mott sets forth the discussion, previously given in full by Hall, regarding "The Physical Strength of the Locust," the conclusion of which is that, if the wave theory be true, this energetic little creature amuses itself by giving bodily motion to some millions of tons with its lively chirrup. Of course, no verification is necessary. The locust is quite able to shatter the wave theory.

The most destructive argument, however, that Dr. Mott includes in his challenge to the world of science may be expressed in his own words: "I am willing to risk the fallacy of the wave theory upon the correctness of one single objection, and that is the slow instead of swift movement of the tuning-fork when sounding audibly and its inability to produce sonorous sound-waves at all as required by the current theory of acoustics." This "slow movement" was first discussed several years ago by Hall and Carter. A fork vibrating 256 times per second continues to produce audible sound after the amplitude of its swing has become exceedingly small. A computation is made to estimate this amplitude at the end of four minutes; and it is thence easily proved that the velocity of the prong is very slight, less indeed than that of the hour hand of a clock. And because this is so, the conclusion is reached that no waves could be propagated through the air from such a slow-moving body. The fallacy of such a conclusion is obvious to any one who has elementary conceptions about the measurement of mechanical energy, but neither Mott nor Hall seems to be included in this class.

The book is sensational, shallow, useless, yet sometimes amusing. The fact that its contents were given in the form of a lecture before the New York Academy of Sciences is sufficient excuse for this notice. No scientific society can insure itself against the occasional introduction of pseudo-science.

*

CRITICAL TEMPERATURE AND PRESSURE OF THE AIR.—Olzewski, having first compressed in Natterer's apparatus some air which contained neither carbonic acid nor watery vapor, introduced it into a glass tube which had been cooled by means of ethylene to temperatures between —142° and —150° C. Under a pressure of fifty atmospheres, there was no meniscus; but on lowering the pressure slowly to 37·6 atmospheres the ebullition of the air became very visible, in the part of the tube which was above the ethylene, and the meniscus was distinctly seen. On increasing the temperature of the air, its pressure also increased, and the meniscus entirely disappeared at a pressure of thirty-nine atmospheres. On repeating the experiment, however, this pressure was found not to be so constant as that at which the liquid air boils, a circumstance which was also remarked in the experiment upon nitrogen. The liquid air does not preserve, in a vacuum, the primitive relations of its elements, the nitrogen evaporating in a larger proportion than the oxygen.—*Comptes Rendus*, July 28, 1884. C.

PNEUMATIC TUBES—The first pneumatic despatch tubes were introduced in Paris in 1867. Eleven years afterwards there were only 33 kilometres in use. Now there are not less than 140 kilometres in the city and 75 offices for sending and receiving despatches.—*Les Mondes*, Nov. 8, 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, May* 20, 1885.]

HALL OF THE INSTITUTE, May 20, 1885.

WM. P. TATHAM, President, in the chair.

Present—185 members and 6 visitors.

The election of eight new members was reported.

Prof. P. H. VAN DER WEYDE, of Brooklyn, N. Y., read a paper on the "Phelps System of Telegraphing to and from Railway Trains in Motion." The paper was fully illustrated with the aid of lantern slides, and by a working model. The paper, with discussion thereon, has been referred for publication. The thanks of the meeting were tendered to Prof. Van der Weyde for his able and instructive presentation of the subject.

Mr. WM. B. LEVAN read a paper entitled "Railway Facilities of the Past and Present," embodying some interesting facts relative to the early history of the methods of transportation in the United States. The paper has been referred for publication.

Mr. FREDERICK IVES presented a further communication on the subject of "Isochromatic Photography," describing certain recent observations which he had made on the comparative value of various sensitizers in photographing colors in the true proportion of their brightness. The paper was instructively illustrated with the aid of projections on the screen. It has been referred for publication.

The Secretary presented a summary of the work of the preparation for the forthcoming "Novelties" Exhibition, and a report on the World's Fair at New Orleans.

The Secretary reported also that the Board of Managers had approved the proposition of the Committee on Exhibitions to make a special award of a "Grand Medal of Honor," to be given to the "Invention or Discovery shown at the Exhibition which shall be held to Contribute most largely to the Welfare of Mankind." A body of examiners will be chosen by the Board of Managers for the purpose of carrying the plan into effect. They will be men of eminent repute, and will be charged with the duty of making a report to the Board, embodying therein the nomination of the invention or discovery which they may deem deserving of the award herein named. The Board of Managers will thereupon take action on the report and recommendation, and, if approved, the award will be made in accordance therewith. In deciding to award this mark of pre-eminent distinction, the Board of Managers have in view not merely the object of influencing the presence of exhibits of a high order of excellence, but also the traditional policy of the Franklin Institute—the encouragement of Science and the Arts.

The Secretary also reported that the Committee of the Franklin Institute to which the nomination of a candidate for the award of the "Albert Medal" of the Society of Arts, was referred, had decided to present the name of its past President, Mr. WILLIAM SELLERS, "for his invention of the system of screw-threads, which was approved by the Institute and adopted as a standard by the Government of the United States; and for his numerous improvements in the design and construction of machine tools, which have become models for the makers of all nations."

The President announced the death of JOHN W. NYSTROM, for many years an active member of the Institute, and who served for several terms on the Board of Managers, and was a frequent contributor to the JOURNAL. He suggested some official action in relation to Mr. Nystrom. Mr. H. R. HEYL, seconded by Mr. WM. B. LEVAN, moved that a committee be appointed to prepare a memorial of the deceased, to be placed on the records. Carried. The President appointed Messrs. H. R. Heyl, Frederick Graff and Wm. B. LeVan.

Adjourned. WILLIAM H. WAHL, *Secretary*.

DECOMPOSITION OF CAST IRON BY HEAT.—Some experiments of L. Forquignon upon malleable iron led him to suppose that cast iron, at a temperature somewhat inferior to its melting point, is decomposed into free graphite and a purer carburet of iron. He accordingly heated cast iron in a vacuum, to a temperature of from 900° to 1,000°C., for several days, without melting or softening. The metal became malleable, and its surface was covered with a dull grayish efflorescence, which produced a mark upon paper or on rough porcelain. The fracture was sometimes of a uniform black, like that of a lead pencil, and sometimes it was dotted with black grains of amorphous graphite, regularly disseminated throughout the mass. It seems probable that this partial decomposition depends upon a tendency to equilibrium between the carbon, the iron and the carburet of iron, the relative proportion of each of these bodies being a function of the temperature. The decomposition of a homogeneous solid into two other solid bodies is a very rare, if not a unique phenomenon.—*Comptes Rendus*, Aug. 4, 1884. C.

THE USE OF FORMENE AS A COOLING AGENT.—Wroblewski having claimed priority for the employment of formene, in producing very low temperatures, stated that his experiments date from the month of March, 1884, while Cailletet did not speak of his own experiments until April. Cailletet replies by a sealed note, which was deposited on December 12, 1881, in which he proposes to apply formene and ethylene in studying the compressibility of nitrogen, hydrogen, etc., at very low temperatures.—*Comptes Rendus*, Aug. 4, 1884. C.

VELOCITY OF THE KRAKATOA WAVE.—Boussinesq, in a letter to M. de Saint-Venant, calls attention to what he considers as the most interesting fact in Verbeek's report upon the great eruption of August, 1883. The wave was propagated by Port Elizabeth, on the southern coast of Africa, with a velocity of 566 kilometres per hour, or 157·22 metres per second. This corresponds almost precisely with Lagrange's formula for the celerity of propagation of long liquid waves when the height of the wave is insignificant in comparison with the depth of the water.—*Comptes Rendus*, May 19, 1884. C.

CONSTITUTION OF CLOUDS.—M. de Tromelin attacks the hypothesis that clouds are composed of vesicles or hollow spheres of condensed vapor. He supposes that every solid body, whatever may be its diameter, retains around it by adhesion a special atmosphere of the gas in which it is plunged; that the thickness of this atmosphere is nearly independent of the volume of the solid body; that the attraction which retains it is within the domain of the molecular forces and is manifested only within very short distances. In this way he accounts for the difficulty of completely removing the air from a tube which is to be filled with liquid. In the case of a vesicle surrounded by its atmosphere the thermal absorption of the water is much greater than that of the surrounding diathermanous air. The atmosphere of the vesicle is consequently expanded and the particle with its atmosphere floats by displacing an equal volume of the circumambient air. The dust particles which are observed in the sun's rays are supposed to be sustained in the same way.—*Les Mondes*, Nov. 8, 1884. C.

RONKAR'S THEOREM.—According to the principle of conservation of energy, every vibratory movement offers an example of the periodical transformation of actual into potential energy and *vice versa*; the total energy alternately becomes wholly actual or wholly potential. In elliptical movement produced by the attraction of a fixed centre, in the inverse ratio of the square of the distance, the total energy is always composed of two parts, one actual, the other potential; the first attains its maximum at the point of the trajectory which is nearest to the centre of attraction, the second at the point which is most distant. E. Ronkar gives the following theorem: In a system of which the movement is periodic and which satisfies the principle of conservation of energy, if the initial conditions of the movement undergo an infinitesimal variation, the increase of the mean potential energy surpasses that of the mean actual energy by a fraction of the latter which is double the relative increase of the period.—*Bull. de l'Acad. de Belg.*, July, 1884. C.

RELATION BETWEEN MOLECULAR WEIGHT AND VELOCITY OF EVAPORATION.—In distilling equal volumes of benzol and water, successively, in the same apparatus and at the same temperatures, it is found that different weights of the two substances pass over in a unit of time. Extensive experiments with water, benzol, chloroform, etc., show that the times for equal weights, at the boiling points, are very nearly in inverse proportion to the molecular weights. C. Schall has examined eleven substances, with very satisfactory results, and he proposes to give the subject a very thorough investigation.—*Beiblätter*, No. 4, 1884. C.

CURIOUS EFFECT OF ASPHALT PAVEMENTS.—It has been noticed that laborers who work barefooted upon asphalt pavements are subject to swelling of the limbs, which has been attributed to the vaporization by the heat of the feet of a small quantity of the petroleum or mineral oil which is contained in the asphalt. The nerves of the feet which govern muscular action and the contraction of the blood-vessels form an extensive and very sensitive nervous network under the arch of the foot where the skin is always thin and the nerves are consequently easily affected.—*Les Mondes*, Nov. 8, 1884. C.

HEALTH EXHIBITION, INTERNATIONAL. LONDON, 1884.

CONFERENCES (as follows):

Bee-Keeping. British Bee-Keeper's Association.
Cobbold, T. S. Parasites of Meat and Prepared Flesh Food.
Cross, C. T. Soap.
De Chanmont, Prof. F. Practical Dietetics.
Domestic Sanitation. Society of Medical Officers of Health. Sanitary Institute of Great Britain. Parke's Museum of Hygiene.
Dwellings for the Poor. Mansion House Council on the Dwellings of the Poor.
Electric Lighting in Relation to Health. Society of Telegraph Engineers and Electricians.
Epidemic Diseases. Epidemiological Society of London.

LECTURES.

Gamgee, Prof. A. Digestive Ferments and Chemical Processes of Digestion.
Meteorology in Relation to Health. Royal Meteorological Society.
Oral Instruction of the Deaf and Dumb. Association for the Oral Instruction of the Deaf and Dumb.
Owen, Edmund. Rearing of Hand-fed Infants.
Sanitary Construction of Houses. Royal Institute of British Architects.
Sanitary Legislation. Social Science Association.
Thudichum, J. L. W. Æsthetical Use of Wine.
Wigner, G. W. Pure Milk.
Wingfield, Hon. Lewis S. History of English Dress.
Williams, W. Mattieu. Science of Cookery.

HANDBOOKS (as follows):

Attfield, J. Water and Water Supplies.
Berdmore, Sept. Principles of Cooking.
Blyth, A. W. Diet in Relation to Health and Work.
Canthi, James. Accidental Injuries.
Cheyne, W. W., Corfield, W. H., and Cassel, C. E. Public Health Laboratory Work.
Duclaux, Dr. Fermentation.
Duff, Harry. Legal Obligations in Respect to Dwellings of the Poor.
Dyke. Acland, Sir Henry W. Health in the Village.
Eassie, Wm. Healthy and Unhealthy Houses.
Edis, R. W. Healthy Furniture and Decoration.
Evatt, G. J. H. Ambulance Organization.
Galton, Capt. D. Ventilation, Warming and Lighting.
Gamger, A. Physiology of Digestion.
Gladstone, Mrs. Healthy Nurseries and Bedrooms.
Goodwin, E. W. Dress, its Relation to Health and Climate.
Guide to Sanitary and Insanitary Houses.
Lakeman, Jas. B. Health in the Workshop.
Lyttleton, Hon. E. and Cobb, G. F. Athletics, Part 2.
Manley, J. J. Salt and other Condiments.
Murphy, S. F. Infectious Diseases and its Prevention.
Old London Street.
Poore, G. V. Our Duty in Regard to Health.
Scott, Wm. B. Cleansing Streets and Ways.
Sparkes, John C. L. Schools of Art.
Thudichum, J. L. W. Alcoholic Drinks.
Warre, Rev. E. Athletics. Part 1

LECTURES.

Ballin, Ada S. Children's Dress.
Blyth, A. W. Old and Modern Poison Lore.
Carr, Henry. Domestic Poisons.
Corfleld, Prof. Foul Air in Houses.

Daily Programme. Monday, October 13th, 1884.
De Chanmont, Prof. F. Prevention of Cholera.
Dixon, H. B. Domestic Use of Gas.
Eassie, W. Healthy Town and Country Houses.
Education. 2d and 3d Editions.
Evatt, Surgeon Major J. G. H. Ambulance Organization.
Galton, Capt. Douglas. Ventilation in Connection with Warmth and Lighting.
Gibert, Dr. J. Dispensary for Sick Children.
Graham, Prof. Charles. Chemistry of Bread Making.
Guide to Exhibition.
Hart, Ernest. Smoke Abatement.
Hodgetts, Prof. Anglo-Saxon Dress and Food.
Hodgetts, Prof. Anglo-Saxon Dwellings.
Lakeman, J. B. Health in the Workshop.
Mariboe, Alex. The Danish Dairy.
Morris, Malcolm. Ethics of the Skin.
Morris, Wm. Textile Fabrics.
Official Catalogue.
Poore, G. V. Thrift in its Relation to Health.
Sheldon, Prof. J. P. The English Dairy.
Smithard, Miss. Dairy Management.
Teale, T. P. Healthy Houses.

Heinrich, O. J. Progress of the Manufacture of Soda by the Ammonia Soda Process. 1884. From American Institute Mining Engineers.

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Hutchinson, E. S. Notes on Coal Dust in Colliery Explosions. 1884. From American Institute Mining Engineers.

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Jacksonville, Florida. Annual Report of Vital Statistics. 1884. From the Health Officer.

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Mayo, Rev. A. D. Building for the Children in the South Washington, 1884.
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Presented by the Board.

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Neill, J. W. Treatment of Nickel-Cobalt Mattes at Mine La Motte. 1885.
From Amer. Inst. Mining Engineers.

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From the Board.

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New Britain, Conn. Report of Health Committee. From the Secretary.

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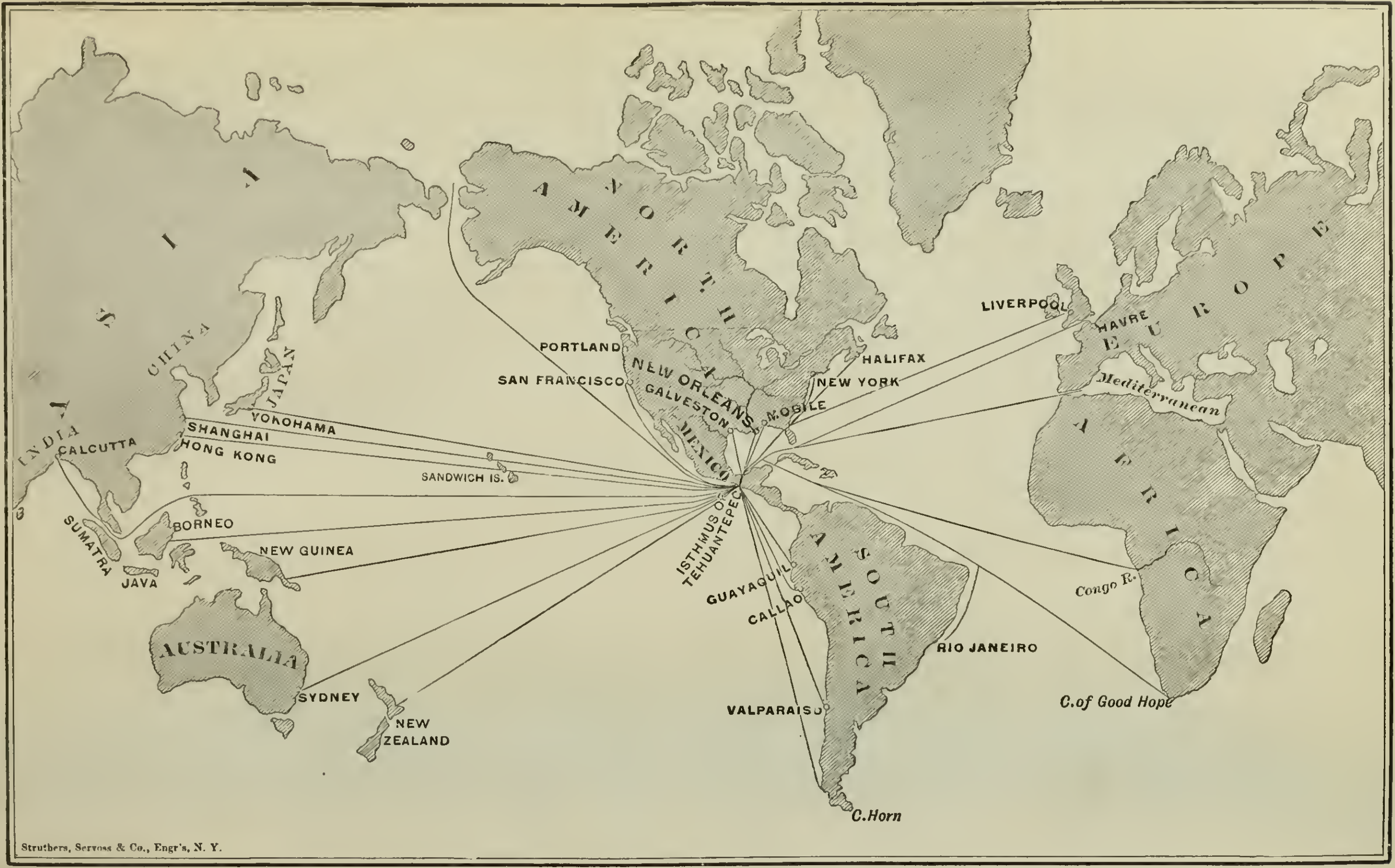
Presented by the Secretary of the Board of Health of the State of Louisiana



The Interoceanic Ship Railway.—Tehuantepec as the Centre of the World's Commerce.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884
OF THE
FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,
FOR THE
PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTIONS V, VI & VIII.

(SECTION IV-B, OF THE CATALOGUE.)

ELECTRIC LAMPS.

CARBONS FOR ARC-LAMPS.

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INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTIONS V AND VIII.—ELECTRIC LAMPS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of Group B, Sections V and VIII, upon Electric Lamps.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *May*, 1885.

Chairman Board of Examiners, International Electrical Exhibition:

DEAR SIR:—I herewith submit the report of "Group B" (Sections V and VIII) upon Electric Lamps. The observations on arc lamps were made; in the main, by Professors Brackett, Young, Geyer, and Anthony, Mr. Hering and Mr. Bussmann. Professors Cross and Mendenhall took part, when present. Occasional assistance was rendered by Lieut. Wyckoff, Lieut. Murdock, and Dr. Dudley. Mr. Eldridge assisted by recording the photometric observations.

The arduous labor of reducing the observations and verifying the results was almost wholly performed by Lieut. Murdock, Secretary of the Group, who deserves the hearty thanks of the other members of the committee for his patience and perseverance in this most uninteresting work.

Respectfully,

WM. A. ANTHONY,
Chairman of Group B.

ITHACA, N. Y., April 24, 1885.

The original scheme of committee work divided observations of electric lamps among four different sections, known respectively as the sections on "Arc Lamps," "Carbons for Arc Lamps," "Incandescent Lamps." and "Photometric Measurements." As the membership of all these sections was the same, it was soon found that this subdivision entailed unnecessary work and needless discussion, and the four sections were therefore consolidated into a group, designated by the Executive Committee as "Group B."* The work of this group covered the whole subject of measurements on electric lamps.

It having been long recognized that observations on incandescent lamps by which the *efficiency* only was ascertained, were unsatisfactory, the desirability of observations to determine the *life* of lamps was obvious, and endeavors were made to organize such a test. The time required for such work prevented the Committee from carrying it out, but the Executive Committee of the exhibition having offered to arrange such a test, the question was considered by the members of Group B, and it was voted that the tests of incandescent lamps should include *duration*, as well as *efficiency* measurements, and that such tests should be carried out under the direction of the Executive Committee of the Franklin Institute for the Exhibition. It was further voted that "Group B" should co-operate in such tests so far as was possible. A duration test was arranged by the Executive Committee, and invitations to take part therein were extended to the various incandescent lamp companies represented in the exhibition. The work of "Group B" was therefore confined to observations of arc lamps.

The examinations of arc lamps consisted mainly in measurements of illuminating power at various angles, from a horizontal plane to sixty degrees below, and in measurements of current and potential at the terminals of the lamp. No attempt was made to examine critically the regulating mechanism, or to measure the resistances of the regulating coils. The examinations were all conducted at the "test-house." Each lamp was supplied with current from the machine for which it was especially designed, and was adjusted and put in operation by the exhibitor, who also regulated the strength of the current.

Currents and potentials were measured by the same instruments employed in measurements of machines. The photometric apparatus and

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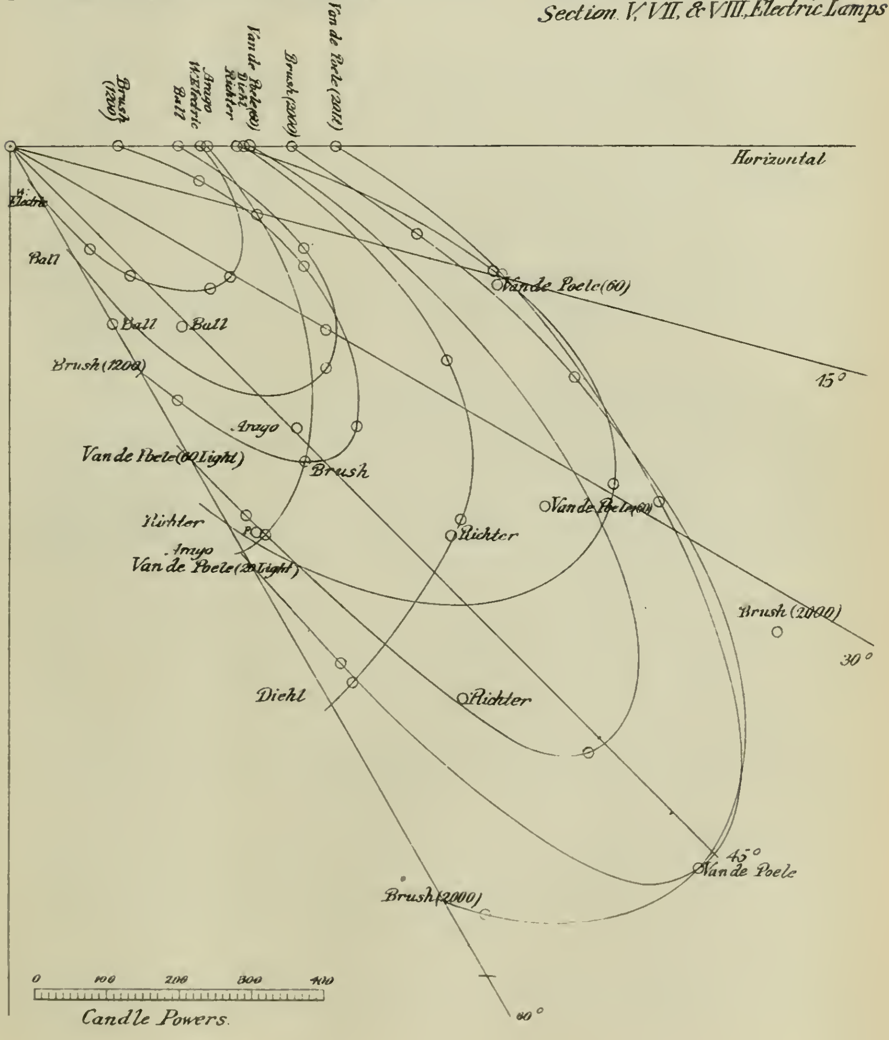
* It was afterwards found advisable to present the report of Section VI, (Carbons) separately from the rest, but it will be found herewith subjoined. —Ed. Com.

International Electrical Exhibition.

Reports of Examiners. Group B.
Section V, VII, & VIII, Electric Lamps.



Candle Powers
of
Electric Lamps, plotted on a
System of Polar Coördinates.

methods deserve a brief description. The standard to which all arc lights were referred was an Argand burner and "Methven's screen," loaned to the committee by Mr. Wright, of Weston's laboratory, which was accompanied by a certificate from the maker to its exactness as a two-candle standard.

It was tested against two standard candles and found to give the same light and to be much more uniform. This standard was placed at one end of a photometer bar of 450 cm. in length, at the other end of which was a 50-candle Swan lamp, serving as a secondary standard. This lamp was fed by a Brush storage battery, furnished and kept charged through the kindness of the representatives of the Brush Company. A second photometer bar making a small angle with the first, extended from this lamp into an adjoining room, where the arc lamp under test was suspended.

To permit of measurements of the light emitted from the arc lamp at various angles with the horizontal, the lamp was suspended from the end of an arm which was free to rotate about a horizontal axis parallel to the photometer bar, but vertically above it at such a height that when the arm was in a horizontal position the lamp could be suspended from its extremity with the arc on a level with the centre of the photometric disc. By this arrangement, when the end of the arm was raised the luminous point described a vertical circle whose axis was a line through the centre of the photometer disc and parallel to the bar. The radius of this circle was 127 cm. and the distance of its plane from the secondary standard 640 cm. At the centre of this circle was placed a mirror of glass, silvered on the back, at such an angle that the light from the arc lamp falling upon it was reflected along the axis of the circle upon the photometer disc. It will be seen that the distance between the lamp and mirror was thus rendered constant for all elevations of the lamp, that when the mirror was adjusted to reflect the light upon the disc, the angles of incidence and reflection were always 45°, and that the distance from the image of the lamp to the secondary standard was always 767 cm. The mirror was carefully tested for absorption and the proper corrections made in the computation of the result.

The general plan of making observations was as follows: The arm from which the lamps were suspended was made horizontal and the height of the lamp adjusted to bring the luminous point on a level with the centre of the mirror and photometer disc. Two observers then adjusted and read the positions of the two discs ten times. The lamp was then raised by raising the end of the arm to which it was suspended and the readings repeated. This was continued until a sufficient number of positions had been taken.

Observations for current strength and for difference of potential between the binding posts of the lamp were made at frequent intervals while the photometric readings were in progress.

To facilitate the comparison of the arc lights with the standard, an apparatus was devised by which one-half or any larger fraction of the light could be cut off at pleasure. This apparatus consisted of a brass disc, about 30 cm. in diameter, having twenty-four sector-shaped openings, all equal to each other and to the metal portions that remained between. Upon this was placed another exactly similar disc, which could be so turned as to close any desired fraction of the openings.

This apparatus was mounted on a spindle placed parallel to the photometer bar, and in such a position that the light from the arc lamp must pass through the openings to reach the photometer disc. When the apparatus was made to revolve at only a moderate rate of speed it was impossible to detect the slightest flicker or inequality in the light in consequence of its use.

In the tests made by your committee, the apparatus was used, when used at all, with the sectors full open, when it was assumed to cut off one half the light as theory would indicate.

Experiment showed that if there is any error in this assumption it is far less than those arising from the unsteadiness of arc lights.

The tables below embody the results of all the tests.

In Table I, column 1 gives the altitudes of the lamp at which the illuminating power was actually measured.

Column 2 gives the true candle power for each altitude after applying all corrections. Each result given is a mean of ten observations.

Column 3, the mean of the observations for current.

Column 4, the mean of the observations for difference of potential between binding posts.

Column 5, the electrical energy consumed by the lamp in Watts.

Column 6, the same in horse-powers.

Column 7 gives the candle-powers for each 15° of altitude from the horizontal to 60°, as deduced from the curves given in X, Plate I.

Column 9 gives the candles per horse-power for the same elevations.

Under the head of remarks are given such observations as were made, during the progress of the tests, as to the working of the lamps.

Table II has been compiled to exhibit the results of the observations as to the steadiness of the light. The several columns give the ratios between the arc light and the standard for each of the ten observations for each altitude.

The plate shows, on a system of polar co-ordinates, the relative intensities of the various lamps tested, and the distribution of the light below a horizontal plane. The advantage of placing an arc lamp at a considerable elevation appears very clearly from an inspection of these curves.

TABLE I.—*Results of Tests on Arc Lamps.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Arago....................	Horizontal	273	15·41	39·87	614·4	·824	Horizontal	273	332	Fifteen lamps in circuit.
	15° 30′	356					15°	350	425	
	30° 15′	505					30°	465	565	
	44° 30′	557					45°	583	708	
	56° 40′	644					60°	645	783	
Ball......................	Horizontal	233	6·60	48·83	322·3	·432	Horizontal	233	539	Seventeen lamps in circuit,
	19° 19′	431					15°	380	880	
	35° 05′	534					30°	520	1,204	
	46° 25′	346					45°	485	1,123	
	60° 00′	284					60°	182	421	
Brush (1,200).........	Horizontal	180	6·62	52·50	347·5	·466	Horizontal	180	386	One lamp in circuit of dead resistance. Lamp very steady, and free from flicker.
	‘ ‘	118						118	253	
	10° 26′	266					15°	332	712	
	22° 11′	439					30°	537	1,152	
	37° 30′	617					45°	613	1,316	
	47°	597					60°	355	762	
	56° 35′	422								

TABLE I.—*Continued.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Brush (2,000).........	Horizontal	389	10·32	56·73	585·5	·785	Horizontal	389	496	One lamp in circuit of dead resistance.
	12° 16′	575					15°	643	819	
	22° 11′	842					30°	1,082	1,379	
	32°	1,253					45°	1,373	1,750	
	58° 40′	1,216					60°	1,200	1,529	
Diehl....................	Horizontal	323	17·67	31·84	562·6	·751	Horizontal	323	428	Four lamps in circuit.
	26° 10′	673					15°	496	658	
	38° 30′	809					30°	725	961	
	56° 40′	881					45°	830	1,101	
							60°	887	1,176	
Richter.................	Horizontal	313	20·19	30·00	605·7	·812	Horizontal	313	386	Six lamps in circuit. Very unsteady. Carbons fed periodically, the current, as shown by an ammeter in circuit, dropping almost to zero, then up to 25 ampères, falling gradually to about 18 ampères, and then dropping to zero again.
	14° 30′	691					15°	700	862	
	29° 15′	956					30°	960	1,183	
	41° 25′	813					45°	894	1,101	
	50° 30′	986					60°	603	743	
	57° 24′	633								

TABLE I.—*Continued.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Van de Poele...... (20-lights.)	Horizontal	451	16·91	37·88	640·5	·858	Horizontal	451	525	One lamp in circuit of dead resistance. Lamp frequently re-adjusted by exhibitor.
	15°	701					15°	708	825	
	28° 40′	1,020					30°	1,060	1,235	
	46° 25′	1,377					45°	1,377	1,604	
	56° 24′	848					60°	670	780	
Van de Poele...... (60-lt. machine.)	Horizontal	333	13·31	45·77	609·2	·817	Horizontal	333	408	One lamp in circuit of dead resistance. Constant flickering, and frequent fluctuations of considerable magnitude.
	16°	700					15°	535	655	
	34°	890					30°	900	1,101	
	46° 25′	1,156					45°	1,162	1,423	
	57° 24′	606					60°	500	612	
Western Electric	Horizontal	263	17·89	25·74	460·5	·617	Horizontal	263	426	Twenty-two lamps in circuit.
	30° 30′	355					15°	323	523	
	35° 15′	310					30°	355	575	
	46° 30′	247					45°	266	431	
	52°	183					60°	75	121	

TABLE II.—*Variations in Intensity of Lights while under Tests.*

ARAGO LAMP.

	Horizontal.	15° 30′	30° 15′	44° 30′	56° 40′
	3·35	4·35	6·10	4·50	9·22
	4·64	3·93	5·73	4·76	4·97
	3·60	5·84	7·93	4·67	9·90
	1·87	4·23	6·46	5·84	5·99
	2·17	5·06	5·87	6·80	7·82
	4·10	3·44	6·68	8·60	9·22
	2·01	4·82	8·66	8·20	11·97
	5·27	3·23	7·13	5·88	14·86
	2·01	.....	8·48	9·22	8·90
	4·10	.....	4·26	15·10	7·67
Mean...........................	3·312	4·36	6·73	7·357	9·052
Standard.........................	69·2	68·4	63·06	63·54	59·76
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles...........................	273	356	505	557	644

BALL LAMP.

	Horizontal.	19° 19′	35° 05′	46° 25′	60° 00′
	2·77	7·12	5·84	5·66	1·49
	2·92	6·18	8·37	2·36	1·67
	3·31	6·85	9·90	4·03	1·63
	3·05	6·42	7·82	6·58	1·42
	3·64	6·18	9·76	2·65	4·38
	3·02	6·85	8·37	6·34	7·42
	3·68	6·94	6·85	9·22	3·68
	3·35	5·58	9·76	7·12	4·94
	3·31	7·12	10·18	4·03	8·96
	3·15	6·42	8·04	4·88	7·03
	....	....	....	....	6·85
	3·222	6·566	8·489	5·287	4·497
Standard.........................	60·6	55·04	52·76	55·46	53·06
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles...........................	233	431	534	346	284

Brush (1,200 Candles).

Horizontal.	Horizontal.	10° 26′	22° 11′	37° 30′	47° 00′	56° 35′
2·68	1·67	4·53	6·42	9·76	9·76	5·84
3·11	1·85	4·59	7·03	10·64	11·27	9·35
3·05	1·81	4·23	7·62	11·11	8·96	7·42
3·11	1·33	4·64	7·62	10·33	10·18	9·62
2·83	1·29	4·33	7·42	9·48	9·48	7·72
3·05	2·53	4·53	7·12	9·48	10·04	6·16
2·83	2·83	4·33	7·42	9·48	9·09	7·92
3·08	1·87	4·13	7·03	9·76	9·76	6·18
2·89	2·71	4·48	7·32	9·90	8·48	6·42
2·77	1·53	4·33	6·34	10·04	9·62	2·53
2·94	1·942	4·41	7·134	9·998	9·664	6·916
54·25	51·06	50·82	51·56	51·74	51·82	51·14
1·192	1·192	1·192	1·192	1·192	1·192	1·192
180	118	266	439	617	597	422

Brush (2,000 Candles).

	Horizontal.	12° 16′	22° 11′	32°	58° 40′
	3·64	5·00	10·33	9·76	14·16
	4·08	4·94	10·33	10·79	16·92
	4·28	5·95	6·34	12·51	14·86
	4·88	4·13	6·94	12·70	13·10
	3·27	6·26	6·50	10·18	11·27
	2·92	4·38	7·32	15·59	14·63
	3·64	6·26	7·42	11·78	5·45
	3·05	4·23	7·52	10·33	9·76
	4·48	8·04	7·22	9·62	10·33
	1·99	4·43	6·50	13·31	6·08
	......	......	......	12·33	......
Mean..............................	3·623	5·362	7·642	11·72	11·656
Standard...	45·05	44·96	46·26	44·84	44·84
Multiplier......................	1·192	1·192	1·192	1·192	1·192
Disc Multiplier............	2·	2·	2·	2·	2·
Candles..........................	389	575	842	1253	1246

DIEHL LAMP.

	Horizontal.	26° 10′	38° 30′	56° 40′
	2·19	6·26	4·76	12·70
	1·77	7·82	7·72	13·51
	1·01	6·18	9·76	9·90
	1·55	7·82	13·51	13·51
	4·28	6·26	9·22	11·96
	7·12	7·82	11·11	9·09
	7·42	7·52	7·82	8·84
	5·68	8·72	12·70	9·35
	1·46	10·95	12·90	9·76
	3·98	7·92	4·94	9·35
Mean..........................	3·646	7·727	9·444	10·797
Standard..	74·38	73·02	71·80	68·44
Multiplier.........	1·192	1·192	1·192	1·192
Candles.........................	323	673	809	881

RICHTER LAMP.

	Horizontal.	14° 30′	29° 15′	41° 25′	50° 30′	57° 24′
	5·06	10·79	15·59	6·26	7·12	3·02
	5·24	13·94	16·11	8·60	10·18	8·60
	6·85	12·70	14·63	8·04	8·37	4·94
	6·18	12·70	15·59	8·60	7·12	4·33
	3·88	13·31	14·39	7·52	10·33	5·68
	3·35	9·90	18·72	5·68	10·04	4·76
	4·76	11·44	18·09	5·00	7·42	3·39
	7·32	11·27	15·59	6·58	7·32	7·62
	6·67	14·16	18·40	6·94	8·96	8·60
	5·38	11·27	16·11	7·52	9·90	6·00
Mean..........................	5·469	12·148	16·32	7·074	8·676	5·694
Standard......................	48·00	47·74	49·14	48·20	47·64	46·64
Multiplier.....................	1·192	1·192	1·192	1·192	1·192	1·192
Disc Multiplier............	....	....	....	2·	2·	2·
Candles.........................	313	691	956	813	986	633

VAN DE POELE (20 LIGHT CIRCUIT).

	Horizontal.	15°	28° 40′	46° 25′	56° 24′
	5·76	·926	6·94	8·04	1·63
	7·03	1·42	3·39	3·98	1·42
	2·83	1·75	3·56	3·68	1·51
	4·03	1·73	4·23	4·94	3·27
	4·28	4·43	4·48	5·60	2·74
	1·55	2·09	4·38	4·45	2·39
	1·87	7·62	3·05	7·62	2·68
	3·08	4·76	4·13	6·76	4·23
	3·60	2·25	3·64	......	6·03
	3·19	2·30	3·68	......	6·10
Mean................................	3·722	2·928	4·148	5·63	3·200
Standard.........................	101·70	100·45	103·04	102·64	111·20
Multiplier......................	1·192	1·192	1·192	1·192	1·192
Disc Multiplier............	....	2·	2·	2·	2·
Candles...........................	451	701	1020	1377	848

VAN DE POELE (60 LIGHT CIRCUIT).

	Horizontal.	16°	34°	46° 25′	57° 24′
	3·39	9·1	15·10	15·85	4·08
	4·18	8·86	16·09	8·84	7·22
	3·02	9·90	14·16	11·27	10·79
	3·80	7·23	17·47	7·62	12·51
	3·84	9·90	10·97	13·51	1·75
	6·34	5·58	2·80	15·10	2·11
	2·59	6·78	6·18	17·79	7·52
	3·80	9·22	8·74	18·40	5·84
	4·13	8·37	6·18	11·78	8·04
	4·33	7·43	6·76	15·34	11·11
Mean	3·942	8·237	10·445	13·55	7.097
Standard........................	70·94	71·30	71·38	71·54	71·66
Multiplier.....................	1·192	1·192	1·192	1·192	1·192
Candles..........................	333	700	890	1156	606

WESTERN ELECTRIC.

	Horizontal.	30° 30′	35° 15′	46° 30′	52°
	4·38	6·94	4·64	3·56	2·62
	4·33	2·98	5·12	3·88	2·80
	1·01	3·80	4·28	5·38	3·72
	5·31	5·12	5·38	2·25	3·68
	2·05	5·06	5·18	1·69	1·63
	7·42	5·12	7·72	3·98	2·68
	4·28	8·72	3·08	3·84	2·59
	5·52	4·70	6·00	4·33	3·19
	2·98	7·32	6·58	6·26	4·18
	5·21	5·76	6·58	5·68	4·38
Mean	4·252	5·552	5·456	4·085	3·147
Standard	51·86	53·56	52·22	50·66	48·8
Multiplier	1·192	1·192	1·192	1·192	1·192
Candles	263	355	340	247	183

NOTE.—The multipliers in Table II are those by which the intensity of the standard is to be multiplied to give the light of arc lamps, as observed. This product is to be multiplied by the constant 1·192, to allow for loss by reflection, and when the revolving disc was used by 2·. The final product is the intensity of the arc lights in candles.

The variation of the multipliers in any one column is therefore a measurement of the inconstancy of the arc light at that altitude. If the actual variations are desired in candles, each multiplier must be multiplied by the intensity of the standard, by 1·192 and when disc is used by 2·.

The foregoing is respectfully presented by

WILLIAM A. ANTHONY, *Chairman.*

C. F. BRACKETT,
G. MORGAN ELDRIDGE,
CHARLES B. DUDLEY,

WM. E. GEYER,
CHAS. A. YOUNG,
A. B. WYCKOFF.

J. B. MURDOCK, *Secretary.*

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

SECTION VI.—CARBONS FOR ARC LAMPS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section VI, on Carbons for Arc Lamps.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *May*, 1885.

Prof. M. B. SNYDER,
Chairman of Board of Examiners,
International Electrical Exhibition:

With the permission of Prof. Anthony, Chairman of Group B, I herewith submit separately the report of Section VI, "on Carbons for Arc Lamps." It includes chemical analyses by Dr. Dudley, Prof. Greene and the chairman, a thorough series of specific gravity determinations by A. E. Outerbridge, Jr., a microscopical study of their transverse sections by Dr. Persifor Frazer, and a table of resistances of the carbons, both plain and copper-coated, made by Prof. Wm. A. Anthony.

Respectfully,

SAMUEL P. SADTLER,
Chairman of Section VI.

CHAS. B. DUDLEY,
Secretary of Section VI.

PHILADELPHIA, *May*, 1885.

Section VI had submitted to it for inspection and report the carbons from five exhibitors, viz.:

1. The Brush Electric Company.
2. The Wallace Carbon Company.
3. The Boulton Carbon Company.
4. The Buffalo Carbon Company.
5. The Carré carbons, manufactured by Emile Levy, Paris, and exhibited by Messrs. J. W. Queen & Co.

Of these, the Brush, Wallace, and Boulton companies submitted plain and copper-coated carbons, the Buffalo Company a homogeneous carbon, both plain and copper-coated, and, in addition, a carbon with a core of pure graphite inserted in a sheathing of coke and a carbon with a vitrified coating, while Queen & Co. offered only the uncoated Carré carbons.

It was determined to have chemical, physical and mechanical studies made of these carbons, but the study of the physical characters, resistance, duration of burning in the lamp under different conditions of current, etc., was handed over to the Section on Arc Lights, whose chairman, Prof. William A. Anthony, agreed to take this part of the work.

[A report on the resistance tests came in after this was written, and is appended.]

The chemical and mechanical study was apportioned out among the members of the Section who now present this report, and included determinations of the percentage of carbon, hydrogen and ash, with a qualitative examination of the chief constituents of the latter in the several plain or uncoated samples, the amount of copper on the coated carbons, both absolutely by weight and relatively per unit of length; specific gravity determinations on the uncoated carbons, both with sections of the solid carbons of given length and with the pulverized material; and, lastly, a microscopical study of the structure of the carbon pencils, using for this purpose specially prepared thin cross-sections. The aid of micro-photography has also been availed of in this latter case for the proper illustration of the results.

1. Determination of the percentage composition of the uncoated carbons (carbon, hydrogen and ash).—This was undertaken by Professor Samuel P. Sadtler, and was made to include five samples, viz.: the plain Brush, Wallace and Boulton carbons, the plain solid Buffalo carbon and the Carré carbon. The Buffalo carbon with the graphite core was not analyzed, as the agent of the company said that the sheathing was made exactly of the same materials and by the same methods as the solid carbon exhibited, while the pure graphite core had a sufficiently well-known composition.

The greater part of a single pencil having been reduced to fine powder, the material for analysis was taken from this stock. The determinations were made by the methods of ultimate analysis, using an open tube, three-fourths filled with granular cupric oxide, placing the weighed material in a platinum boat, and conducting over this a slow stream of oxygen. In this way, besides the carbon and hydrogen determinations, the ash could be accurately weighed, and a check established upon the whole.

The results were as follows:

	Brush Carbons.			*Wallace Carbons.*		
	I.	II.	Average.	I.	II.	Average.
Carbon	97·61	97·81	97·71	95·92	......	95·92
Hydrogen	1·32	1·22	1·27	1·15	0·97	1·06
Ash	0·64	0·61	0·63	2·94	2·80	2·87
Occluded air or loss	0·43	0·36	0·39	......		0·15
	100·00	100·00	100·00	100·01		100·00

	Boulton Carbons.			*Buffalo Carbons.*		
	I.	II.	Average.	I.	II.	Average.
Carbon	98·19	98·24	98·21	97·68	......	97·68
Hydrogen	0·72	......	0·72	1·51	1·60	1·55
Ash	0·87	0·88	0·87½	1·09	1·08	1·09
Occluded air or loss	0·22		0·19	......		......
	100·00	99·12	99·92	100·28		100·32

	Carré Carbons.		
	I.	II.	Average.
Carbon	95·98	95·84	95·91
Hydrogen	1·00	0·73	0·86
Ash	1·91	1·83	1·87
Occluded air or loss	1·11	1·60	1·36
	100·00	100·00	100·00

In looking at these figures, several points of interest at once present themselves.

The Brush carbons have the smallest ash of the series. On account of their rather more open and porous structure, there is room for occluded air in this case, as the result shows.

The Wallace carbons have the largest amount of ash of the series.

The character of this ash will be noted farther on by another member of the Committee. This carbon is closer in structure than the Brush carbon, being made in an entirely different way, and there is no occluded air to look for.

The Boulton carbons, though having a higher percentage of ash than the Brush carbons, have a higher carbon and a lower hydrogen percentage, possibly having been burned at a higher temperature.

The Buffalo carbons show a distinctly higher percentage of ash than the Brush or the Boulton carbons. The hydrogen percentage as given is possibly a little too high, as the summing up seems to show.

The Carré carbons show a large ash, although considerably less than the Wallace carbons. The porous structure of these hydrocarbons offers, no doubt, a partial explanation for the relatively large percentage of occluded air and loss.

2. Determination of the percentage of ash and qualitative examination of same.—This was undertaken by Dr. Charles B. Dudley, and the examination was made upon a portion of the same pulverized material as that used by Prof. Sadtler in the combustion analyses. The results were as follows:

The Brush carbons yielded 0·478 per cent. of ash. A qualitative examination showed that the portion insoluble in acids was slight; that there was a considerable amount of ferric oxide and a trace of magnesia.

The Wallace carbons yielded 2·672 per cent. of ash. A qualitative examination showed a large insoluble residue and a large amount of the oxides of copper and iron.

The Boulton carbons yielded 0·892 per cent. of ash. A qualitative examination showed a small insoluble residue only, a large amount of ferric oxide and a trace of magnesia.

The Buffalo carbons yielded 1·104 per cent. of ash. A qualitative examination showed a small insoluble residue, much ferric oxide, and a trace of magnesia.

The Carré carbons yielded 2·086 per cent. of ash. A qualitative examination showed considerable insoluble residue, much ferric oxide, and considerable lime.

It will be seen that these ash determinations correspond quite generally, in some cases with great exactness, to those gotten in connection with the combustion analyses of the carbons.

Sample.	Length of coating.	Copper on length of 4 c. m.	Copper per centimetre.	Total copper (not including that on end).
Brush carbon......	281 millimetres.	·1621 grammes.	·040525 grammes.	1·1388 grammes.
Wallace carbon...	297 "	·0180 "	·0045 "	0·1337 "
Boulton carbon...	272 "	·1853 "	·046325 "	1·2600 "
Buffalo solid carbon....................	262 "	·1010 "	·02525 "	0·6616 "
Buffalo core carbon....................	253 "	·1525 "	·038125 "	0·9645 "

3. Determinations of copper on the copper-coated carbons.—These were made, by Prof. Wm. H. Greene, upon the samples of the Brush Company, the Wallace Company, the Boulton Company, and both the homogeneous and the graphite-core carbon of the Buffalo Company. No copper-coated sample of the Carré carbon was exhibited. The results are given in tabular form on page 17.

4. Specific gravity determinations.—These were undertaken by A. E. Outerbridge, Jr., and were made upon the uncoated carbons of the Brush, Wallace and Boulton Companies, the French Carré carbon and the plain, the graphite-core and a glazed carbon of the Buffalo Company.

A superficial examination of these carbons showed that some of them were much more porous and of coarser grain than others; it was thought advisable, therefore, to make two different determinations of each sample, one for the purpose of ascertaining the specific gravity of the pencil and the other the specific gravity of the material of which the pencil is composed.

For the first method the samples were all cut to the same length, viz., 5 centimetres. These were first heated to a moderate temperature to expel the moisture absorbed in their pores and further dried in a desiccator; when quite cool they were weighed upon a delicate analytical balance, sensitive to less than one-tenth of a milligram. The pencil was then coated with shellac varnish to prevent the absorption of water when immersed. When the thin coating of shellac was hard the sample was suspended from the beam by a filament of silk and reweighed; this was the weight used in the specific gravity determinations. The sample was then immersed in a beaker glass of distilled water at 60°F. and weighed. The specific gravity of the pencil was then determined by the usual calculation.

In order to determine the specific gravity of the material of which the pencils are composed, it was first ground to a fine powder in a steel mortar, put through a "No. 80" sieve, warmed to expel moisture, dried in the desiccator and weighed. The weight taken in this case was usually two grammes. The specific gravity bottle which was used in these determinations was filled each time with distilled water at, or very near, 60°F., and weighed; the water was then poured out, the powder put in, the bottle refilled with water (care being taken that no air-bubbles remained) and reweighed; from which data the specific gravity of the sample was determined.

In addition to the above, two other experiments were made, as follows: The pencil was broken up in the mortar and the finest particles separated by the sieve; the coarser grains were weighed, thrown into distilled water and boiled. The water was then cooled down to 60°F., the granules transferred to the specific gravity bottle and a new determination made. In both cases, the specific gravity was much higher than that of the finely powdered portion of the same sample, as will be seen from the tabular statement appended. This would seem to indicate that some volatile gas was driven off during the process of boiling.

A further observation was made, viz.: that the material composing the pencils is not of uniform density. When the sample is finely powdered, thrown into water and stirred with a glass rod, a portion sinks, but another portion (somewhat like an oily scum) floats upon the surface. This is doubtless some pitch or tar compound used to cement the materials together. Most of the carbons used in actual practice are coated with a superficial layer of copper, and as this would render specific gravity determinations of no value, the plain carbons only were used with the exception of one sample exhibited by the Buffalo Co., covered with a coating of borate of lead. There was also a carbon pencil examined having the peculiarity of a central core (resembling graphite) a little larger in diameter than the core of an ordinary lead pencil.

It was noticed when these different determinations were tabulated that the specific gravity of the powdered carbon was (as might be expected) in each case greater than that of the pencil, and furthermore that the pencils showing the highest specific gravities were not made from the densest materials. Considerable difference was also noticed in the hardness of the different samples.

The figures given in these tables are the average of two weighings of the same sample after drying.

Carbon Pencils.

Name of Sample.	Length.	Weight.	Specific Gravity.
Brush	5 centimetres.	7·8035 grammes.	1·526
Wallace	do.	8·5667 "	1·571
Boulton	do.	7·7162 "	1·516
Buffalo—plain	do.	7·7272 "	1·523
Buffalo—graphite core	do.	7·0540 "	1·415
Buffalo—vitrified	do.	8·5961 "	1·598
Carré	do.	8·6091 "	1·506

Ground Carbon.

Name of Sample.	Weight.	Specific gravity
Brush	2 grammes.	1·587
Wallace	do.	1 806
Boulton	do.	1·606—1·540 Average, 1·573
Buffalo—graphite core	do.	centre core, 1·699 exterior, 1·594
Buffalo—vitrified	do.	1·865
Carré	do.	1·885—1·914 Average, 1·8995

The following table shows the specific gravity of the two coarsely powdered samples which were boiled in distilled water.

Brush carbon	2 grammes taken	sp. gr., 1·908
Carré	do	sp. gr., 1·982

5. *Microscopical examination of thin transverse sections of the carbons.*—This was made by Dr. Persifor Frazer and yielded the following very interesting results.

The examination of the five thin sections of the electric light carbons submitted was undertaken with an 8–10 Zentmayer lens and a Beck parabolic reflector.

The sections were in fair order (with the exception of some dirt on the inner surfaces of the cover glasses) except that No. 5 was broken across the cover glass and the latter as well as the carbon section detached from the slide.

No. 1, was taken from a Brush carbon.
No. 2, was taken from a Wallace carbon.
No. 3, was taken from a Boulton carbon.
No. 4, was taken from the Buffalo Co.'s carbon.
No. 5, was taken from the Carré carbon.

The preliminary examination was made without a reflecting mirror and with a low eye-piece giving a magnifying power of about 50 diameters.

No. 1. Under these circumstances No. 1 presented an opaque surface except in a few spots where the film was torn away, and a few translucent particles. The color of its surface was silver gray with foliated masses of carbon of decidedly graphitic appearance distributed through the field.

Under the reflected light of the parabolic mirror the substance of the section, though of coarser structure than appeared in the other slides, seemed of considerable constancy of composition.

The largest grains were about 0·1 mm., and the smallest 0·03 mm., the latter measurement quite accurately representing the size of the pores. All the bright spots are surfaces showing high metallic lustre and gray color, with lines of striation and fracture.

No. 2. Without the reflector, No. 2 presented the appearance of a fine-grained surface covered with small rounded nodules or minute botryoidal masses, and showed little if any traces of foliation or crystallization.

Under reflected light (and exposed on the underside to a parallel beam) the largest opaque grains were 0·03 mm. and the smallest 0·015 mm. The average size of the opaque grains was 0·02 mm. These are, in a rough estimate, from 1 to 2 per cent. of visible foreign matter in the carbon in the form of grains of various substances (which are generally translucent) in the carbon. Some of these reach a size of 0·1. There are fewer pores in this than in No. 1, but those which exist are larger.

The largest part of the substance is very fine grained, but large dark gray angular discs are very generally distributed throughout the mass. In the photograph these dark gray flat bodies are visible, and the constituent parts of the fine mass are less sharply defined and separated. But, in fact, the photograph cannot give either the color or the lustre of the original, and is mainly useful in giving an idea of the texture of the surface.

No. 3. Without the reflecting mirror, No. 3 showed an extremely fine-grained texture with comparatively few and quite small points of silver-gray color and metalloid lustre.

Under the mirror, the grains measured from 0·05 to 0·02.

The texture was extremely fine-grained and compact, and the structure exceedingly homogeneous. The color of the surface was a lighter gray than that of any of the other slides, and was tinged yellowish in irregular blotches which may, however, have been the result of the accidental addition of a foreign body in mounting. Occasional translucent oblong particles were seen measuring 0·1 mm. to 0·05 mm. along their longer sides.

The surface exhibits small and large masses of slightly greenish color attached to each other and nowhere separable into distinct grains. The smallest of these constituent parts are not so small as those of the matrix of No. 2; and the largest, not as large as the dark angular fragments in the same slide. The structure is nowhere compact, but loose and spongy. There are visible a few small striated particles of irregular outline.

No. 4. Without the mirror the texture appears very fine, but little granular in character. The very small points of steel-gray color of graphitic aspect are less numerous than in 2 and 3.

With the reflector, the grains varied in size from 0·01 mm. to 0·03 mm., the average being rather nearer to the first measurement. The color was a somewhat darker gray than that of No. 3, and the number of very minute particles of foreign matter was greater, most of these were translucent and measured about 0·02 mm.

No. 5. Examined simultaneously in reflected and transmitted light, No. 5 shows a very large number of holes which have doubtless been caused by the more ready crumbling of certain of its constituent grains. Those of the latter which are opaque measure from 0·02 mm. to 0·01 mm. The grains are not so fine as in the last specimen, and the structure seems to be less homogeneous.

From the existence of numerous very fine points of various colors in transmitted light, and the existence of the holes formerly mentioned, it would seem that the powdered carbon has been mixed with very fine sand or earth, either accidentally or purposely, before having been moulded into sticks.

The ground mass has a fine grained, dark greenish appearance of the same character as that of 3 and 4, *i. e.*, resembling a surface of a

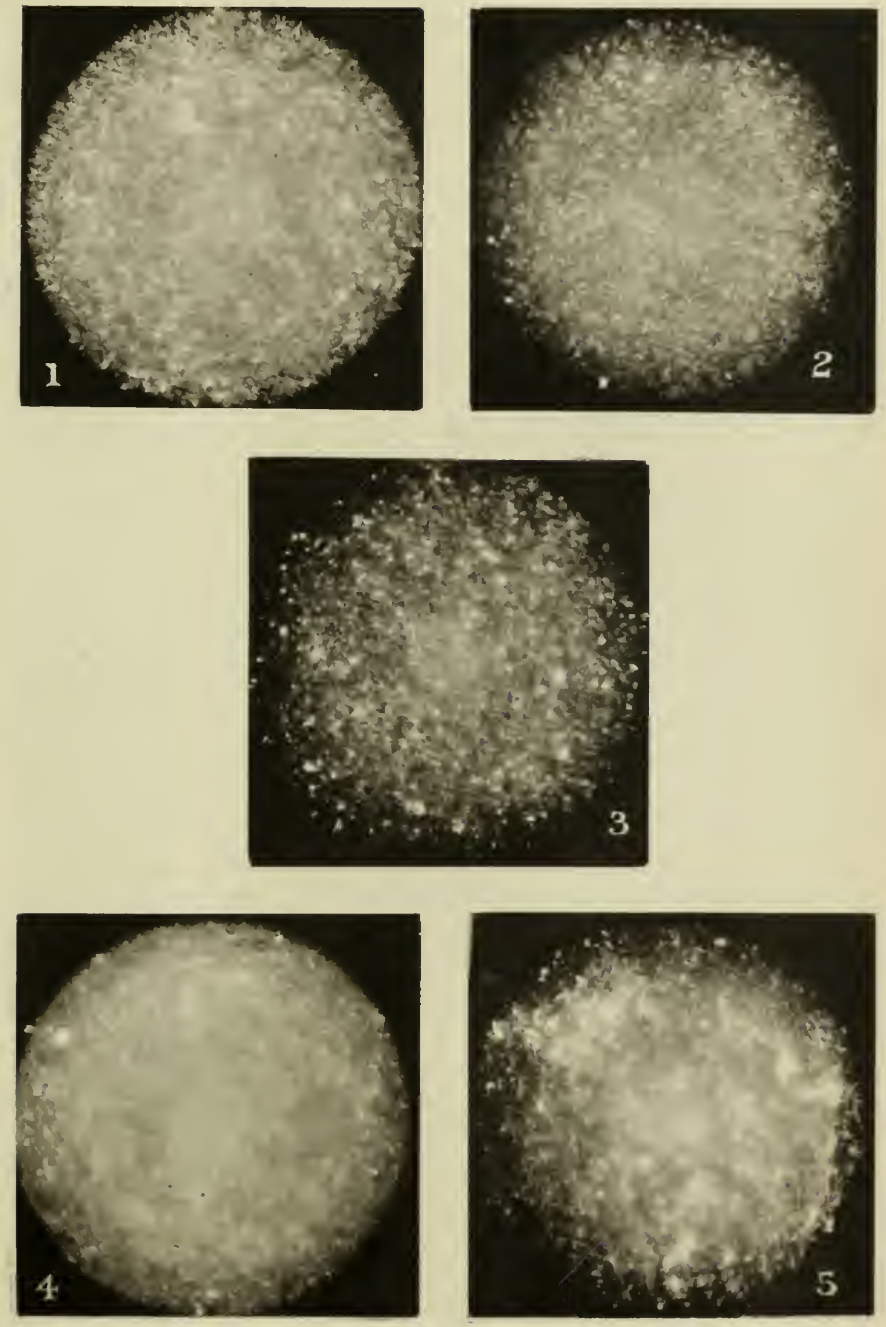


PHOTO-COLLOTYPE

[illegible]

CARBONS FOR ARC LAMPS.

Photographs through the Microscope of thin Sections of Electric Light Carbons, to accompany Dr. Frazer's report.

decomposing mineral. A number of dark gray, flat, angular objects are scattered through the mass as in No. 2.

RESISTANCES OF ARC LIGHT CARBONS.

The following measurements of resistances of electric light carbons were made at Cornell University last winter. The carbons were selected at random from those which Professor Sadtler procured for tests, and probably represent a fair average.

The method pursued in measuring the resistances was as follows: The carbon to be tested was connected in circuit with a piece of very uniform German silver wire, a known length of which measured $\frac{1}{10}$ ohm. To connect the carbon in the circuit, a hole, which the carbon fitted tightly, was bored in the side of a wooden block, and a second hole bored from the top of the block to meet the first. Such a block was fitted upon each end of the carbon and the vertical holes filled with mercury. Into this the connecting wires were placed. The resistance of the carbon was determined by obtaining, upon the German silver wire, points having the same difference of potential as points on the carbon near the two ends. Measuring the distance between these points on the German silver wire, and comparing with the known length for $\frac{1}{10}$ ohm, gave the resistance of the carbon. To determine the points of equal difference of potential, a Thomson galvanometer of 10,000 ohms resistance, differentially wound, was used. The coils were adjusted so that no deflection occurred when the same current flowed in opposite directions through them. Their resistances were also adjusted to exact equality. The terminals of one pair of coils were then connected with points near the ends of the carbon, and the terminals of the other pair with sliding contacts on the German silver wire. The method of using the instrument will now be evident. It was far more sensitive than was necessary for the purpose, but could nevertheless be used with great facility. The measurements were made by Mr. E. T. Turner, a young man doing some post-graduate work in my laboratory. The results are given in the table below:

Resistances of Carbons.

No. of Carbons.	Resistance per Centimeter.	Total Resistance of 30 c.m.
	WALLACE (PLAIN).	
	ohm.	
1	0·0048	0·134
2	0·0044	0·132
3	0·0047	0·141
	(COPPERED.)	
4	0·0044	0·132
5	0·0031	0·093
	BUFFALO COMPANY (VITRIFIED).	
1	0·0050	0.150
2	0·0066	0·198
3	0·0061	0·183
	BRUSH (PLAIN).	
1	0·00610	0·183
2	0·00623	0·187
3	0·00672	0·222
4	0·00691	0·227
	(COPPERED.)	
1	0·00108	0·0324
2	0·00033	0·0099
3	0·00024	0·0072
	BUFFALO (PLAIN).	
1	0·00625	0·187
2	0·0052	0·156
	(COPPERED.)	
1	0·00221	0·076
2	0·00940	0·0144
3	0·00075	0·0225
	CORED (PLAIN).*	
1	0·1413	4·239
2	0·1700	5·100
	(COPPERED.)	
1	0·000422	0·01266
2	0·001617	0·04851
	BOULTON (COPPERED).	
1	0·00165	0·0489
2	0·00218	0·0654
3	0·000475	0·001425
	CARRE (PLAIN).	
1	0·00408	0·1224
2	0·00377	0·1131

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*This was a hollow carbon having a core of some different material. To make sure that the high resistance was not a mistake, it was measured also in the ordinary way by the bridge, with the same results.

Respectfully submitted,

SAMUEL P. SADTLER, *Chairman Section VI.*
CHAS. B. DUDLEY, PERSIFOR FRAZER,
WM. H. GREENE, WILLIAM A. ANTHONY,
A. E. OUTERBRIDGE, JR.

NOTE.—Sincere thanks are due to Mr. William Curtis Taylor for the care, skill and time he has contributed to render the photographic plate as successful as possible. P. F.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884
OF THE
FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,
FOR THE
PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTIONS XIV--XVI AND XXX,

(SECTION I, CLASSES II AND III, OF THE CATALOGUE.)
AND
(SECTION VII, CLASSES II AND III, OF THE CATALOGUE.)

BATTERIES.

MACHINERY AND MECHANICAL APPLIANCES

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, APRIL, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

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INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XIV.—BATTERIES.

To the Board of Managers of the Franklin Institute:

GENTLEMEN:—I have the honor of herewith transmitting to you the report of Sections XIV, XV and XVI, of the Board of Examiners. The material for the latter two Sections was but meagrely represented at the exhibition, and they were therefore merged with Section XIV.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *February* 16, 1882.

Prof. M. B. SNYDER,
Chairman of Board of Examiners,
International Electrical Exhibition:

I herewith submit the report of the Section on Batteries. The factors of the primary batteries were measured by Prof. Dolbear, who was aided in the readings by Dr. William Drysdale and Prof. Greene. The measurements of secondary batteries were made by Profs. Van Dyck and Greene, aided in the readings by Drs. Drysdale and James, Prof. Sadtler and Mr. J. Morgan Eldridge. Mr. P. H. Russell, not a member of the Board of Examiners, was of valuable service in the tests of both primary and secondary batteries, and the examiners hereby express their thanks.

Respectfully,
F. C. VAN DYCK,
President of Section XIV.

WM. H. GREENE.
Secretary of Section XIV.

REPORT ON BATTERIES.—SECTION XIV.

There were thirteen varieties of batteries offered for examination. Most of these were represented by as many as two cells and one by five cells.

The committee was not asked to examine any cell to determine its fitness to do a certain kind of work. It therefore considered each kind of a cell as a device for furnishing a difference of electric-potential in an electric-circuit, and for maintaining a current of electricity for such an interval of time as was at the disposal of the committee for its observation.

The uses to which a galvanic battery may be put are so various and the capabilities of different cells are so different that the committee felt some embarrassment at the outset in settling upon a plan of observations that could be completed in the limited time, which would be given to it, and at the same time not do injustice to a class of galvanic cells capable of excellent work in a way different from that of another class.

Roughly, batteries may be classed in two divisions, namely: I, closed circuit batteries or those adapted to be kept in constant working circuit, such as the various forms of Daniel's cells; and II, open circuit cells, or those adapted to intermittent service, and which require more or less time after use to recover their ability to do further work at the same rate as at first, as is the case with the various forms of ammonium chloride cells; but in the majority of cases when a battery is wanted it is wanted for immediate current strength, and a knowledge of the rate of decrease in strength, or of the time a given cell may be depended upon to furnish a current of given strength will enable one to judge fairly as to the availability of a given cell for a known purpose.

Now the current which a given cell will yield at any instant depends upon the electro-motive force of the cell at that instant, and the total resistance in its working circuit. The total resistance in the circuit, includes, of course, the internal resistance of the cell itself, and this factor is a very variable one, and most discordant results are obtained when it is measured under different circumstances; such for instance as with small and with great external resistance. It happens also that the electro-motive force of a cell as measured by the difference of potential of its terminals, and the electro-motive force available in a closed circuit with the cell may be very different quantities.

The one depending upon the kind of materials used in the cell and their disposition, the other varying with the resistance external to the cell.

Hence it becomes necessary to ascertain the electro-motive force of the cell without a circuit, that is to say, the difference of electric-potential between its terminals when no current can flow, which will, of course, be the total electro-motive force in any circuit of which it may form a part. The determination of this electro-motive force of each cell was therefore the first work attempted, and the committee chose as a standard of electro-motive force, that of a Daniel cell (Wiedemann pattern). It was not the business of the committee to fix the absolute value of this cell as a standard, and they therefore adopted a value nearly that generally recognized for such a cell.

The following determinations of the electro-motive force of a Daniel cell have been made by different persons:

Sir William Thomson	1·122	Volts.
Lord Rayleigh	1·072	"
Kohlrausch	1·138	"
Daniel	1·124	"
Clarke	1·11	"
Barker	1·02	"
Carhart	1·122	"
Ordinary assigned value	1·079	"

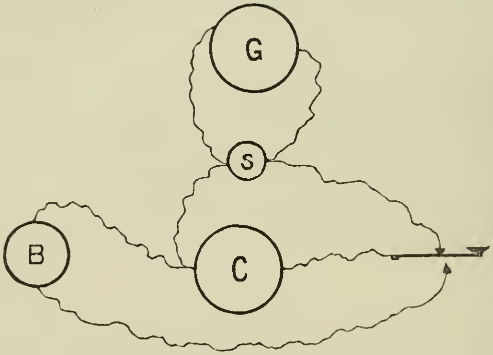
The method of determining relative electro-motive forces was such that the values obtained were simply proportional to the deflections of the galvanometer needle which were carefully read to single divisions of the scale.

The standard Daniel cell used gave 83 divisions on the scale, while a Latimer-Clarke Standard cell made by Weston gave 110 divisions, and a Leclanche cell 118. The electro-motive force of a Clarke's Standard is to that of the Daniel as 110 to 83. Assume that of the Daniel as being 1·10 volts, and that of the Clarke cell becomes 1·457 volts which is precisely what Clarke gives for it. If Lord Rayleigh's determination of the value of Clarke's cell 1·435 volts be adopted, then that of the Daniel should be 1·082—a trifle more than that generally assigned which is 1·079.

The committee adopted 1·10 volts as being the standard of the electro-motive force of the Daniel cell and all computations have been made on that assumption. If any one would assign a different value from the one here employed, he is furnished will all the data necessary for calculating the electro-motive force of any cell examined.

The *method* of determining the electro-motive force is as follows: The battery to be examined has its terminals touched to a condenser for an instant which becomes charged to the same potential as the cell. The condenser is then instantly discharged through a galvanometer and the deflection noted.

The accompanying diagram will serve to show the attachments and working of this method.



G, is the galvanometer; S, its shunt; C, the condenser; and B, the battery to be tested.

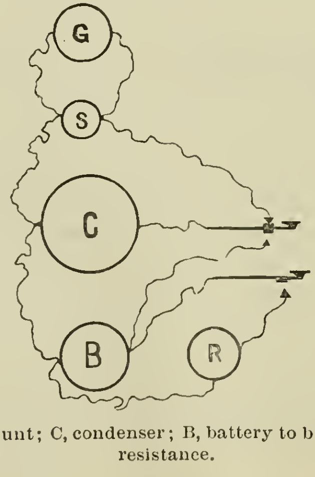
When the key is pressed down, the battery is connected to the terminals of the condenser, which becomes charged, and when the key is raised the condenser discharges through the galvanometer, and the battery is thrown out of circuit. On account of the necessary delicacy of the galvanometer, it is essential that it be used in a place not subject to vibratory movements, nor in proximity to masses of iron or magnets or electrical currents. No place about the exhibition building could be found free from these disturbances, but, through the courtesy of Dr. Barker, of the University of Pennsylvania, we were provided with all the conveniences we needed; not only with a suitable room, but with galvanometers, shunts, condenser, Wheatstone's bridge, etc. The galvanometer had a resistance of 3,732 ohms, the condenser a capacity of $\frac{1}{2}$ a microfarad. An electrometer reversing key was used to discharge the condenser.

With this apparatus and arrangement, readings of the deflections were taken for each cell; seldom more than five, however, if they were uniform, which was generally the case.

Table of Electro-motive Force of Cells.

Name of Cell.	No.	Deflec.	E. M. F. (volts).
Standard Daniel	1	83	1·1. Assumed.
Leclanché (carbon in porous jar)	1	132	1·73. Just set up.
“ “ “	2	135	1·76 “
“ “Prism Cell” (zinc in porous cup)	1	118	1·54 “
“ “ “ “	2	118	1·54 “
“ “ free zinc	1	118	1·54 “
“ “ “	2	119	1·55 “
“ diamond carbon	1	110	1·44 “
“ “	2	110	1·44 “
Bergman calomel cell	1	104	1·37 “
“ “	2	95	1·26 “
“ “	3	99	1·31 “
“ “	4	99	1·31 “
“ “	5	100	1 32 “
Partz's small cell	1	111	1·47 “
“ “	2	106	1·40 “
“ large cell	1	149	1·97 “
“ “	2	134	1·77 “
“ iron cell	1	74	·98 “
“ medical cell	1	122	1·22 “
“ “ small cell	1	120	1·6 “
Flemming's modified Leclanché (portable)	1	81	1·07
“ “ “ “	2	110	1·46
“ Leclanché prism	1	117	1·55. Up 4 days.
“ “ “	2	118	1·55 “
“ cabinet	1	109	1·45
“ “	2	105	1·39
Partz's large cell	1	149	1·97. Up 3 days.
“ “	2	134	1·77 “
“ iron cell	1	74	·98 “
“ medical cell	1	122	1·61
“ “	2	120	1·6
Diamond carbon	2	94	1·24. Up 4 days.
Siemens-Halske	1	83	1·10
Fitch chlorine cell	1	98	1·3
“ “	2	95	1·26
Oxide of copper cell	1	.....	·90
“ “ “	2	.....	·76

Batteries differ in their rate of output of electrical energy, and also in their constancy. It is true that if one knows the electro-motive force of a circuit and its resistance, he may know the strength of the current in that circuit, as that is given at once by Ohm's law; but it is also true that when a battery furnishes the electro-motive force, both the electro-motive force and the resistance of the cell change, each tending to lessen the strength of the current; and, as both fluctuate, it is of but little use to depend upon what is ordinarily called the internal resistance of the cell as being its working resistance. For instance, a certain cell has an electro-motive force of 1·75 volts on open circuit and at the same time an internal resistance of 1·19 ohms. When in circuit with 5 ohms external resistance, observations made every half-minute for two minutes, show the following increase of internal resistance, 1·19, 1·25, 1·25, 1·31, 1·45, which, of course, decreases the current. Still, as there is a wide difference between cells as to their potential, depending upon their internal resistance, which adapts them to certain kinds of work, it is desirable to know its value in order that one may know about what to expect from a given cell. Just as the electro-motive force of the cell was determined in open circuit, so the internal resistance of the cell was measured, and is as nearly as possible the resistance of the cell as a conductor.



G, galvanometer; S, shunt; C, condenser; B, battery to be measured; R, variable resistance.

Each cell was tested for its internal resistance by the same condenser method, closing the circuit of the battery through a known external resistance and without any delay discharging the condenser, which was shunted upon the same battery terminals, the interval never being greater than a quarter of a second between the closing of the battery circuit and the discharge of the condenser. Thus the battery was not allowed to polarize appreciably.

NAMES OF CELLS.	E. M. F., open circuit.	E. M. F., closed circuit.	External resistance.	R, total resist. in circuit.	$R - r$, internal resist. in ohms.
Leclanché Disque No. 1.	130	109	5	6	1·
" " No. 2.	134	112	5	6	1·
Bergman's Cells, average of 5	100	88	5	5·68	·68
Diamond Carbon No. 1.	94	85	5	5·53	·53
Siemens-Halske No. 2.	83	36	5	11·5	6·5
Partz's Large Cell No. 1.	149	135	5	5·51	·51
" " " No. 2.	134	123	5	5·44	·44
" Iron "	74	69	5	5·3	·3
" Medical " No. 1.	122	87	2	2·8	·8
" " " No. 2.	120	94	2	2·45	·45
Flemming,s Leclanché, portable	81	31	5	13	8·
" " "	111	47	10	23·5	13·5
" Cabinet Cell No. 1.	109	52	10	21	11·
" " " No. 2.	105	50	10	21	11·
Leclanché Porous Cell No. 1.	128	80	2·17	3·47	1·3
" " " No. 2.	122	80	2·17	3·3	1·3
" "Prism," zinc in porous cup No. 1.	115	79	2·17	3·15	·98
" " " " " " No. 2.	117	79	2·17	3·12	·95
" " free zinc No. 1.	118	83	2·17	3	·83
" Diamond Carbon No. 2.	94	78	2·17	2·61	·44
Fitch's Chlorine Cell No. 1.	98	73	5	6·7	1·7
" " " No. 2.	95	61	5	7·8	2·8

As the electro-motive force is instantly distributed through the circuit, one is practically measuring the difference of potential between the terminals of a coil having a known resistance, and the electro-motive force in any part of the circuit, is to the total electro-motive force in the circuit as the resistance in the part is to the whole resistance. Let E be the total electro-motive force in a circuit, R the total resistance, e the electro-motive force between two points in the circuit having a known resistance r, then $E : e :: R : r$ and $R = \frac{Er}{e}$. $R - r$ is the resistance of the cell. The above diagram illustrates the connections for such observations.

In order that this value of R should be the true value, it is essential that the battery circuit should not be closed long enough to permit polarization. This may be effected by so arranging the keys that both circuits may be closed by the same movement or by employing a separate key and closing the battery circuit first and as soon as possible afterwards the other, which may be done very easily within the fourth of a second, by counting "one, two; one, two"; at the rate of twice a second; closing the battery circuit on one and the condenser circuit on two, letting up both instantly; this was the method followed in this series of observations.

The known resistance in R of the diagram was generally one of the coils in a Wheatstone Bridge, and was generally considerably greater than the resistance of the cell itself.

The above table gives the electro-motive forces and resistances thus measured.

CURRENT STRENGTH OF CELLS.

The current strength in any conductor with a given resistance is determined by the difference of electrical potential between the terminals of the conductor, and varies directly as such difference of potential. Also, the fall of potential between any two points in a conductor will be proportional to the resistance between those points. It follows that the current strength in a coil may be accurately determined by measuring the resistance of the coil and the difference of potential at its terminals. The resistance of a coil of wire may be measured with very great precision, and the difference of potential by the method described is accurate to two decimal places when the readings are to single divisions on the scale, which we deemed sufficiently close for this purpose.

By observing the deflection produced by the condenser with open circuit, one determines the total electro-motive force of the circuit, by observing the deflection produced on any closed circuit, one determines the relative electro-motive force between the points chosen. In the present instance the external resistance was generally 2·17 ohms, it being made up of a galvanometer coil having a resistance of ·56 of an ohm and a small free coil with a resistance of 1·61 ohm. As the electro-motive forces are proportional to the deflections, and the resistance external to the cell is constant, the current strength is proportional to the deflections. When observations are made at intervals for several minutes the difference of potential is generally found to fall, owing chiefly to the increase of resistance in the cell. The following table gives the strength of current in ampères furnished by each cell named, for a time given in minutes indicated. The external resistance being, as already stated, 2·17 ohms generally.

This table has nothing to say as to the life of a cell. There was not time enough at the disposal of any member of the Committee to run each cell down to its minimum working capacity. In order to do such work, it would be necessary to have duplicate apparatus for observations, and days would have been needed for some single cells, such as Partz's. Neither does the table indicate the rate of recovery of a cell after use, but it gives reliable information as to the available current from a given cell on such a short circuit as was employed here, and in general it is true that a cell will maintain a degree of constancy the greater the resistance it is worked through. Of course, if the cell is used so long or so vigorously as to materially change the chemical constitution of the acting liquid, the electro-motive force will suffer reduction, and there is no time rate that can be applied with any degree of accuracy. It is also to be remarked that when cells are coupled serially for working, the electro-motive force available in the circuit will not be the product of the electro-motive force of one cell into the number of cells, but a fraction of that which will vary with the number of cells in circuit, the loss being about one volt for fifteen volts; and fifteen or twenty for one hundred volts, and this, too, with fair insulation.

* * * * * * * * *

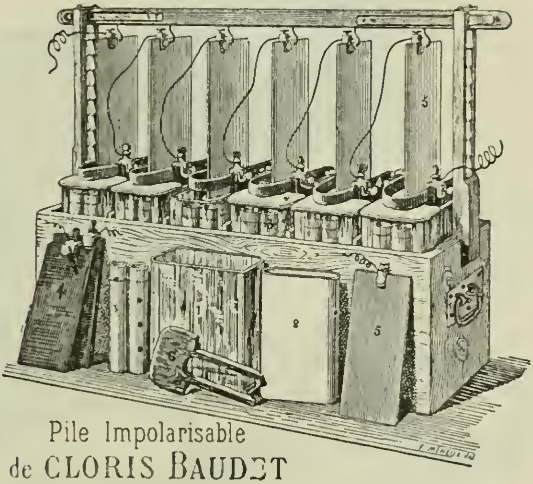
James W. Queen & Co. exhibited a battery cell called the *Chloris Baudet,* which for some reason failed to reach the examiners at the time the other cells were examined, and not being disposed of, on account of its high cost it was soon sent back to Paris. On account of the claims made for this cell it was thought best to construct one and test it. The cut represents one of these batteries of six cells. It is called an unpolarizable battery on account of its constancy of action. The following is a description of the cell by Baudet. The outer rectangular cell I, 22 cm. by 18 × 9. A porous cell 2, for the

Current Strength, in Amperés, at Intervals in Minutes.

NAMES OF CELLS.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30	40	50	60
Partz Cell.......... No. 1.	·70	....	....	....	....	·68	....	....	....	....	·67	....	....	....	....	·66	·65	·64	·63	·61	....	......
" " ....No. 2.	·66	....	....	....	....	·64	....	....	....	....	·62	....	....	....	....	·60	·59	·59	·58	·56	·54	·53
" Iron Cell............	·26	....	....	....	....	·25	....	....	....	....	·25	....	....	....	....	·25	·25	·25	....	·25	....	......
Leclanché Porous Cell, No. 1.	·48	....	·48	....	·47	....	·46	....	·45	....	·45	....	·44	....	....	....	......	....	....	....	....	......
Leclanché Porous Cell, No. 2	·48	....	·48	....	·47	....	·47	....	....	....	......	·46	....	....	....	....	....	....	....	....	....	......
Leclanché Prism, zinc in porous cell	·47	....	·43	....	·42	....	·41	....	·40	....	·40	....	·40	....	....	·39	....	....	....	....	....	......
Leclanché Prism, zinc in porous cell.........	·47	....	·46	....	·43	....	·41	....	·41	....	·40	....	·40	....	·39	·38	....	....	....	....	....	......
Leclanché Prism, free zinc..........	·49	....	·47	....	·47	......	·46	....	·45	....	·45	......	·43	....	·43	....	....	....	....	....	....	......
Leclanché Diamond Carbon.....................	·47	....	·43	....	·40	....	·39	....	·38	....	·36	....	·35	....	·34	·34	....	....	....	....	....	......
Bergman's Calomel	·41	·40	....	·39	....	·39	....	·39	....	·39	......	....	·39	....	....	....	....	....	....	....	....	......
Siemens and Halske...	....	....	·16	....	·14	....	·14	....	·14	....	·14	....	....	·14	....	....	....	....	....	....	....	......
Flemming's Cabinet...	·12	....	·09	....	....	....	....	....	....	....	......	....	....	....	....	....	....	....	....	....	....	......
" Portable.	·13	·09	......	·07	....	....	....	....	....	....	......	....	....	....	....	....	....	....	....	....	....	......
Partz Open Circuit......	·30	....	·28	....	....	·27	....	·25	....	·23	......	....	·21	....	·19	....	....	....	....	....	....	......
" Medical Cell......	·42	....	·39	....	·31	....	·27	....	·24	....	......	....	....	....	....	....	....	....	....	....	....	......
Fitch's Chlorine..........	·29	....	....	....	·32	....	....	·33	....	·34	......	....	·34	....	....	·34	....	....	....	....	....	......

zinc plate 5. Two porous jars 3, one for crystals of bichromate of potash, the other for sulphuric acid; one with holes and the other without; two plates of carbon 4, each with suitable wire connections, and a suitable cover 6, for the whole, to maintain the points in their places. The solutions consist of a saturated solution of bichromate of potash, with sulphuric acid as for the ordinary bichromate battery for the outer jar containing the carbon, and a super-saturated solution of acid sulphate of potash $KHSO_4$, for the porous jar containing the zinc. The undissolved sulphate may remain in the bottom of this porous jar. Common salt may be used as a substitute for the potassium sulphate.

Batterie de 6 Eléments Impolarisables

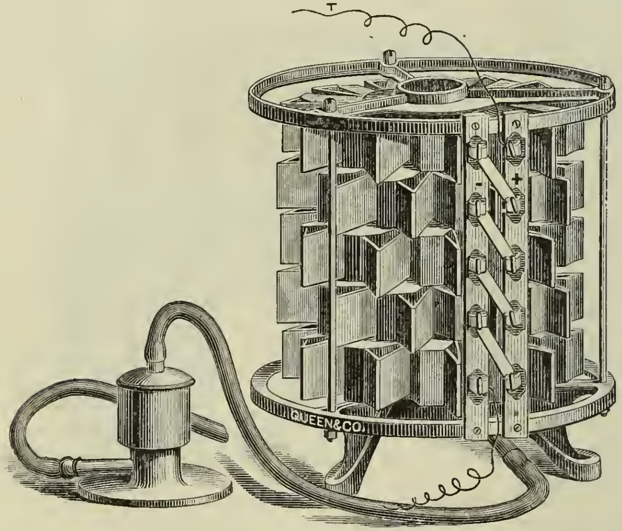


Pile Impolarisable
de CLORIS BAUDET

In the cell constructed for the test, the bi-sulphate of potash was used in the porous jar. When first set up, this cell had an electro-motive force of 1·87 volts. It was then put in short circuit with an external resistance of 5·8 ohms, including the galvanometer, when the deflection was 47°, with a current of ·262 ampères. As the constant of the galvanometer was ·245, it followed that the internal resistance of the cell was 1·3 ohms, which is a small resistance for a cell for constancy, but the immersed zinc was but about 3 inches of a half inch rod. The needle fell one degree in the first five minutes, where it remained for an hour, when it rose to 47½°, where it stood steadily for five hours; the next morning it was at 45°. It remained practically constant for about 28 hours, when it suddenly fell; evidently some of the material had been used up. This is a surprisingly good record for a cell, and surpasses the Grove, the Bunsen, or the common bichromate cells a long way.

THERMO-ELECTRIC BATTERIES.

Jas. W. Queen & Co. exhibited two of the modern thermo-batteries, one of Clamond and two of Nöe-Rebicek. The Clamond consisted of pairs of iron and an alloy of bismuth and antimony, arranged in rings. There were 14 rings of 11 pairs each; 154 pairs. This was found to give an electro-motive force of 3·02 volts, and to have while hot an internal resistance of 2·2 ohms.

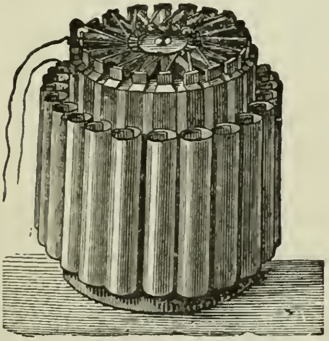


Clamond Thermo-Electric Battery.

The following is the statement of the maker of the Clamond batteries:

No. of Elements.	E. M. F. in Volts.	Int. Resist., ohms.	Gas per hour required.
50	1·8	·3	350 litres.
100	3·6	·6	450 "
150	5·4	2·	350 "

The Nöe-Rebicek thermo-piles consisted of twenty pairs of German silver and an alloy of zinc and antimony. One of the specimens had twice the cross-section of the other one. The larger had an electromotive force of 1·94 volts, or nearly one-tenth of a volt per pair. The smaller one gave 1·73 volts. The internal resistance of the larger was ·5 ohm, and of the smaller ·8 ohm. The Nöe-Rebicek battery has the highest E. M. F. of any thermo-battery that has been made on a commercial scale, and seems a long step away from the ordinary bismuth-antimony pile, and towards a thermo pile that may be used as a substitute for the common galvanic battery. They are made of 20 elements each for a single pile, or as the substitute for a single battery cell, and any number of them may be combined, as is the case with battery cells, and arc and incandescent lighting effected or other electrical work done with them. They may be heated by gas or alcohol flame. A. E. D.



In Mr. A. Partz's large cell he employs a plate of carbon, half an inch in thickness and three inches wide, divided by saw-cuts into six vertical prisms of half-inch sectional area. He claims that this form gives a stronger and more constant current than a closed plate, and in accordance with his desire the following test was made:

Two similar plates of half inch carbon were obtained, and one of them was divided by sawing into half inch prisms which were left united at the ends. These plates were successively coupled with the same plate of zinc and immersed in a solution of potassium pyrochromate and sulphuric acid. The current strength was measured by the aid of a delicate ampèremetre with an unvarying resistance interposed.

The following figures show the ratios of the strengths of current under these circumstances:

	Closed plate.	Open plate.
On closing circuit	1·25	1·30
After one minute	1·10	1·15
After two minutes	1·075	1·125
After three minutes	1·05	1·10
After four minutes	1·0375	1·10
After five minutes	1·025	1·10

W. H. G.

REPORT ON POROUS CELLS.

Made and Exhibited by J. E. Jeffords & Co., 1412 *Salmon Streets, Philadelphia.*

The two cells tested were of the same size, about 3 × 8 inches, and differed in color only, so far as could be seen. One cell was of white ware, and the other of a light buff ware.

Resistance was determined in a solution of copper sulphate, the cells being filled to the level of the surrounding solution. The height of liquid in each case was six and three-sixteenths inches. The results were

	White.	Buff.
Time to wet through with water	3½ min.	5½ min.
Fall of water by leakage in forty-eight hours	$2\frac{3}{16}$ in.	1¾ in.
Resistance in ohms, of $6\frac{3}{16}$ inches in height	·69	1·14

F. C. Van D.

TESTS OF SECONDARY BATTERIES.

As soon as practicable after the organization of the section for the consideration of secondary batteries, a copy of the following scheme was addressed to each of the three parties making an exhibit of such batteries. The conditions were accepted by the *Railway Light and Power Company,* and by the *Brush Company,* but the parties exhibiting the *Star Battery* declined having their battery examined, and ignored the communication of the examiners.

SCHEME PROPOSED FOR THE EXAMINATION OF SECONDARY BATTERIES.

The tests for secondary batteries will be confined to efficiency, and no report will be made on duration.

"Exhibitors will be required to furnish batteries in first-class condition, and the size, thickness of plates, and distance between them will be measured. The composition of liquid used must be stated to the examining committee, and it is desirable that the manner of preparing plates shall be made known.

The batteries will first be charged with a current of whatever strength may be designated by the exhibitor, and will be allowed to run down through their normal external resistance until the electro-motive force, as shown by the weakest cell, begins to diminish. The discharging will then be stopped, and the battery will be recharged, and at intervals of fifteen minutes the counter electro-motive force of the battery and the strength of current will be measured. When the battery is fully charged, as shown by disengagement of gas, an artificial resistance equivalent to that for which it is claimed the battery is adapted, will be substituted for the dynamo at the charging terminals, and the battery will be allowed to run down as before measuring at intervals of fifteen minutes the electro-motive force, and the strength of current until the electro-motive force begins to fall rapidly.

After making these tests the batteries will be again charged, under conditions identical with the first, and will be sealed for two, three or more days, as may be found practicable by the examining committee, after which they will be discharged through a resistance identical with the first, and the loss of energy due to standing, will be determined. If time be sufficient, the committee will measure the internal resistance of each battery.

Reports will indicate the size, thickness and number of plates, their distance apart, the composition of liquid employed, the number of cells, the weight of battery, the counter electro-motive force, the ampère-hours required for charging, the ampère-hours in discharging through the measured resistance for which it is stated the battery should be efficient, the loss of energy between charging and discharging, and the loss of energy occasioned by allowing the battery (charged) to remain idle during stated intervals of two, three or more days as may be found practicable by the committee."

The instruments used in the measurements were an Ayrton and Perry ammeter, a Carpentiers' voltmetre, and an Ayrton and Perry voltmetre. The ammeter was placed as near as practicable to the battery, and so arranged that it remained in the circuit during both charging and discharging. The voltmetre was in a short circuit connecting with the poles of the battery, measuring the counter electromotive force during charging, and the direct electro-motive force of the discharge during which the resistance, consisting of a number of incandescent lamps in parallel circuit, was practically substituted for the machine used in charging. The committee had resolved to discharge the batteries through an invariable resistance of German silver ribbon or wire, but finding that it would be obliged to have the apparatus constructed at its own expense, it was compelled to adopt the incandescent lamp resistance as the only feasible one.

Notwithstanding all efforts it could not succeed in having the ammeter calibrated until after the termination of the actual measurements. The calibration then obtained was far from satisfatory, as it covered only a portion of the scale of the instrument, but it appeared to indicate that the actual readings were slightly lower than they should have been in the upper degrees of the scale. A recalculation of the results with these corrections introduced made it appear probable that the efficiencies found and given further on are about one per cent. too low. However, as the Committee is not perfectly satisfied with the corrections, and as the practical difference is quite small, it has not been deemed advisable to use other figures than those given by the direct readings of the instrument.

The battery tested for the Railway Light and Power Company, consisted of thirty-four cells, each 11 by 12 by 3 inches, containing four plates each, 9 by 10 by $\frac{3}{16}$ inches. The plates are formed by Faure's process, red lead being compressed into an excavated surface. This battery was charged by a Weston dynamo, and was used at the Exhibition to run six or eight incandescent lamps of different resistances.

It was discharged by the committee on the evening of the 8th October, until the electro-motive force at the poles on closed circuit was 44·14 volts, and was recharged and again discharged between the morning and night of the following day. The installation of the battery was very bad. The connections between the plates were made by lead bolts which could not be properly tightened, and the battery was placed on a carpet which was kept continually moist by the acid spray thrown up by the bubbles of gas produced towards the close of the chargings. These faulty conditions may account for the low efficiency found for the battery.

The discharge was effected through a resistance consisting of sixteen Weston lamps. When the discharge was stopped on the 8th October, the electro-motive force on closed circuit was 44·14 volts, on open circuit 53·5 volts. On the 9th October, after verifying the electromotive force, the battery was charged with 299376·825 volt-ampère-minutes. The discharging was then begun, and an energy representing 159659·649 volt-ampère-minutes had been expended in the lamp resistance before the electro-motive force on closed circuit had fallen to 44 volts.—the potential at the poles while the battery was doing work at the close of the discharge in the morning.

The efficiency of the battery was therefore

$$\frac{159659\cdot649}{299376\cdot825}$$

or 53·66 per cent. in its delivery of energy compared with the energy required for charging.

The fall of potential in this battery was very unevenly distributed among the cells. On beginning the discharge at 5.30 P. M., on the 9th October, the electro-motive force of the separate cells was uniformly 1·9 volts. Between this time and 7.15 P. M., the electro-motive force of the battery fell from 64·2 to 60·19 volts, the potential of the separate cells taking equal part in the fall. At 7.30 a difference in potential became apparent among the cells, and the electro-motive force began to fall rapidly. One cell was at 0 potential at 8 o'clock, three at 8.15, four at 8.30 and five at 9.10, while the electro-motive force of the other cells was but little below that at starting the discharge.

As may be seen in the tabular statement, the battery was charged during four hours and forty-eight minutes, at the average rate of 1039·5 volt-ampères. It yielded during discharge for four hours and ten minutes the average rate of 638·6 volt-ampères.

From 786·45 volt-ampères, which was maintained sensibly constant during the first hour, the delivery fell to 699·36 at the end of the second hour, 557·57 at the end of the third, and 416 at the end of the fourth.

The results of the first test of this battery convinced the committee that the cells were in such a condition that any further measurements and tests for holding charge would be entirely devoid of scientific interest, and of no benefit to the Institute or the exhibitors.

Tabular Statement of Observations and Results of Calculations of Tests made on Secondary Battery exhibited by the Railway Light and Power Company, *9th October*, 1884.

Time of observation.	Dif. of potential at poles. *Volts* = E.	Current, ampères = C.	E × C, volt-ampères.	Mean E × C, between observations.	Total energy of charge, E × C × minutes.
10.42 A.M.......	77·6	10·5	814·800	....	....
11.00................	77·6	13·0	1008·800	911·800	16412·400
11.15................	77·6	14·0	1086·400	1047·600	15714·000
11.30................	77·6	14·0	1086·400	1086·400	16296·000
11.45................	77·6	12·0	931·200	1008·800	15132·000
12.00 M............	78·9	13·0	1025·700	978, 450	14676·750
12.15........	78·9	13·5	1065·150	1015·425	15681·375
12.30.......	80·25	14·0	1123·500	1094·325	16414·875
12.45................	80·25	14·5	1163·625	1143·562	17153·438
1.00 P.M..	80·25	15·0	1203·750	1183·688	17755·312
1.15................	80·25	14·5	1163·625	1183·688	17755·313
1.30................	81·59	14·0	1142·260	1152·942	17294·137
1.45................	80·25	12·0	963·000	1052·630	15789·450
2.00................	81·59	12·25	999·478	981·238	14718·581
2.15........	82·9	12·5	1036·250	1017·864	15267·956
2.30................	81·59	12·0	979·080	1007·665	15114·975
2.45................	81·59	11·75	958·682	968·881	14533·219
3.00................	81·59	10·5	856·695	907·689	13615·331
3.15................	82·9	13·0	1077·700	967·197	14507·963
3.30................	82·9	12·0	994·800	1036·250	15543·750
					299376·825

Time of charging, 4 hours 48 minutes. Average rate of charging = 1039·5 volt-ampères.

Discharging through Sixteen Weston Lamps.

Time of observation.	Dif. of potential at poles. Volts = E.	Current, ampères = C.	E × C, volt-ampères.	Mean E × C, between observations.	Total energy of discharge. E × C × minutes.
5.30 P.M……….	64·2	12·25	786·450	…………	…………
5.45……………….	64·2	12·25	786·450	786·450	11796·750
6.00…………….	64·2	22·25	786·450	786·450	11796·750
6.15 ……………	63·13	12·25	773·342	779·896	11698·414
6.30……………….	62·86	12·0	751·320	763·831	11457·469
6.45……………….	62·86	12·0	754·320	754·320	11314·800
7.00……………….	61·53	11·75	722·978	738·619	11079·731
7.15…… ……….	60·19	11·75	707·232	715·105	10726·575
7.30……………….	58·85	11·75	691·488	699·360	10490·400
7.45……………….	58·85	11·75	691·488	691·488	10372·312
8.00……………….	56·18	11·0	617·980	654·734	9821·006
8.15 …………….	53·5	10·75	575·125	596·553	8948·288
8.30……………….	52·43	10·3	540·029	557·577	8363·655
8.45……………….	49·76	10·0	497·600	518·814	7782·218
9.00……………….	49·49	9·25	457·782	477·691	7165·369
9.10….. ….. ……	47·08	9·25	435·490	446·636	4466·362
9.20 .. ………….	46·01	9·2	423·292	429·391	4293·910
9.30…………….	45·48	9·0	409·320	416·306	4163·060
9.40….. ………..	44·14	8·5	375·190	392·255	3922·550
					159659·649

Time of discharging, 4 hours 10 min's. Average rate of discharge = 638·6 volt-ampères.

$$\text{Efficiency} = \frac{159659{\cdot}619}{299376{\cdot}825} = 53{\cdot}66 \text{ per cent.}$$

The secondary battery tested for the Brush Electric Company consisted of nineteen cells, each containing three plates 16 by 16 inches, the total weight of lead per cell being about one hundred pounds. These plates are said to be formed by the Planté's process, alternating currents being passed between cast lead plates immersed in dilute sulphuric acid. The cells were in good condition and the connections of the plates were soldered.

The Carpentier volt-meter used was calibrated by this battery, and the readings being 1·91 volts per cell throughout the whole scale employed, may be considered sufficiently exact.

On the 12th of October the battery was discharged through 41 Swan lamps in parallel circuit, until the difference of potential at the terminals had fallen to 29 volts, the current flowing being then 38·25 ampères. Before starting to recharge on the 13th of October, the electro-motive force on open circuit was 36·3 volts, and with 40 lamps in the circuit 29·8 volts. The recharging was then begun at 9 A. M., and was continued until 10 P. M. of the same day, with an interruption of fifty-nine minutes due to an accident to the engine.

After charging the battery it was discharged through 43 lamps. The electro-motive force on open poles was 38 volts; with the lamps in circuit 34 volts. The current passing through the lamps was 46·75 ampères.

As will be seen in the accompanying table, 562202·25 watts were required to charge the battery from a potential of 29 volts on closed circuit, while in discharging down to the same point 390454·625 watts were obtained. The efficiency ratio is therefore

$$\frac{390454{\cdot}625}{562202{\cdot}250}$$

or 69·45 per cent.

Appended are graphic expressions of the rise and fall of potential during charging and discharging, and of the energy absorbed and delivered by the battery. The curves and the columns of the table showing the fall of potential and the energy obtained from the battery, indicate that while there is a gradual weakening of the whole battery, the principal falling off is due to the sudden weakening of individual cells, and that the latter do not run down uniformly.

The test of the Brush secondary battery was sufficiently severe, as the charging was done with a somewhat heavier current than is usually recommended for the purpose, and the discharging was at an exceedingly rapid rate. It was therefore decided that after the test for holding charge had been made the battery should be recharged and discharged through a smaller variation in electro-motive force, but at a slower rate.

The battery was recharged on the 16th of October and locked up by the committee who held the keys for ten days. In the mean time we had been requested to return the instruments which had been placed at our disposal. As the Franklin Institute authorities could not guarantee that the instruments would again be placed in our hands for the resumption of the tests before the battery was required to be moved, the committee decided that it was not advisable to prolong work for which the facilities had been withdrawn. With the consent of the Brush Company, further tests were therefore abandoned.

Tabular Statement of Observations and Calculated Results of Charging Brush Secondary Battery, 13*th October*, 1884.

Time of Observation.	Dif. of potential at poles. *Volts* = E.	Current passing through battery. *Amperes* = C	E × C. Volt-ampères	Mean E × C between observations.	Total energy of charge. E × C × minutes.
9.00 A. M.	39·5	19·5	770·250	…………	……………
9.15	40·5	19·0	769·500	769·875	11548·125
9.30*	37·5	Engine stopped.	769·500	769·500	7695·000
10.24	39·5	19·75	780·125	…………	……………
10.30	40·5	20·00	810·000	795·063	4770·375
10.45	40·25	19·75	794·938	802·469	12037·031
11.00	40·0	19·75	790·000	792·469	11887·031
11.15	40·0	19·75	790·000	790·000	11850·000
11.30	39·75	19·25	765·187	777·594	11663·906
11.45	39·75	19·25	765·188	765·187	11477·813
12. M	39·5	19·25	760·375	762·781	11441·719
12.15	39·5	19·0	750·500	755·437	11331·562
12.30	39·25	19·0	745·750	748·125	11221·875
12.45	39·25	18·75	735·937	740·844	11112·656
1.00 P. M.	39·25	18·75	735·938	735·938	11039·063
1.15	39·0	18·5	721·500	728·719	10930·781
1.30	39·25	18·75	735·937	728·719	10930·781
1.45	39·25	18·5	726·125	731·031	10965·469
2.00	39·25	18·5	726·125	726·125	10891·875
2.15	39·25	18·5	726·125	726·125	10891·875
2.30	39·25	18·5	726·125	726·125	10891·875
2.45	39·25	18·5	726·125	726·125	10891·875
3.00	39·5	19·0	750·500	738·312	11074·688
3.15	39·5	19·0	750·500	750·500	11257·500
3.30	39·25	19·0	745·750	748·125	11221·875
3.45	39·5	19·0	750·500	748·125	11221·875
4.00	39·5	19·0	750·500	750·500	11257·500
4.15	39·5	19·0	750·500	750·500	11257·500
4.30	39·6	19·25	762·300	756·400	11346·000
4.45	39·7	19·25	764·225	763·263	11448·937
5.00	39·7	19·0	754·300	759·262	11388·938
5.15	39·6	19·7	780·120	767·210	11508·150
5.30	39·8	19·6	780·080	780·100	11701·500
5.45	40·0	19·6	784·000	782·040	11730·600
6.00	40·25	19·6	788·900	786·450	11796·750
6.15	40·25	19·6	788·900	788·900	11833·500
6.30	40·5	19·7	797·850	793·375	11900·625
6.45	40·5	19·65	795·825	796·838	11952·563
7.00	40·75	20·0	815·000	805·412	12081·187
7.15	41·0	19·8	811·800	813·400	12201·000
7.30	41·2	19·5	803·400	807·600	12114·000
7.45	41·6	19·75	821·600	812·500	12187·500
8.00	42·0	19·6	823·200	822·400	12336·000
8.15	42·0	19·5	819·000	821·100	12316·500
8.30	42·5	20·0	850·000	834·500	12517·500
8.45	43·0	19·5	838·500	844·250	12663·750
9.00	43·5	19·5	848·250	843·375	12650·625
9.15	44·5	19·0	845·500	846·875	12703·125
9.30	45·0	19·0	855·000	850·250	12753·750
9·45	46·0	19·0	874·000	861·500	12967·500
10.00	47·0	19·25	901·750	889·375	13340·625
	40·56	19·26			562202·250

* Engine stopped from 9·25 to 10.24.

Total time of charging, 12 hours 1 minute. On open poles at 9 A. M. = 36·3; at 10 P. M = 39·0.

Tabular Statement of Observation and Calculation of Results of Discharging through Incandescent Lamp Resistance, Brush Secondary Battery, 13*th and* 14*th October*, 1884, *immediately after charging.*

Time of Observation.	Dif. of potential at poles. *Volts = E.*	Current. *Amperes = C.*	E × C. Volt-ampères	Mean E × C between observations.	Total energy of discharge. E × C × minutes.
10·47 P. M........	34·0	46·75	1589·500	....	....
11·00.................	34·0	46·75	1589·500	1589·500	20663·500
11·15.................	33·5	46·75	1566·125	1577·813	28667·188
11·30.................	33·5	46·75	1566·1i5	1566·125	23491·875
11·45.................	33·25	46·5	1546·125	1556·125	23341·875
12·00.................	33·25	46·5	1546·125	1546·125	23191·875
12·17.................	33·2	46·25	1535·500	1540·812	26193·812
12·30.................	33·0	46·0	1518·000	1526·750	19847·750
12·45.................	33·0	45·5	1501·500	1509·750	22646·250
1·00 A. M.........	33·0	45·0	1485·000	1 93·250	22398·750
1·15.................	32·5	45·0	1462·500	1473·750	22106 250
1·30.................	32·0	44·25	1416·000	1439·250	21588·750
1·45	32·0	44·0	1408·000	1412·000	21180·000
2·00.................	31·5	43·5	1370·250	1389·125	20836·875
2·15.................	31·25	43·0	1343·750	1357·000	20355·000
2·30.................	31·0	42·0	1302·000	1322·875	19843·125
2·45.................	30·5	41·25	1258·125	1280·063	19200·938
3·00.................	30·0	40·25	1207·500	1232·812	18492·187
3·15.................	29·25	39·0	1140·750	1174·125	17611·875
3·18.................	29·0	38·75	1123·750	1132·250	3396·750
	32·135	44·188			390454·625

Total time of discharge, 4 hours, 31 minutes.

$$\text{Efficiency} = \frac{390454 \cdot 625}{562202 \cdot 250} = 69 \cdot 45 \text{ per cent.}$$

Reported by Wm. H. Greene, and F. C. Van Dyck.

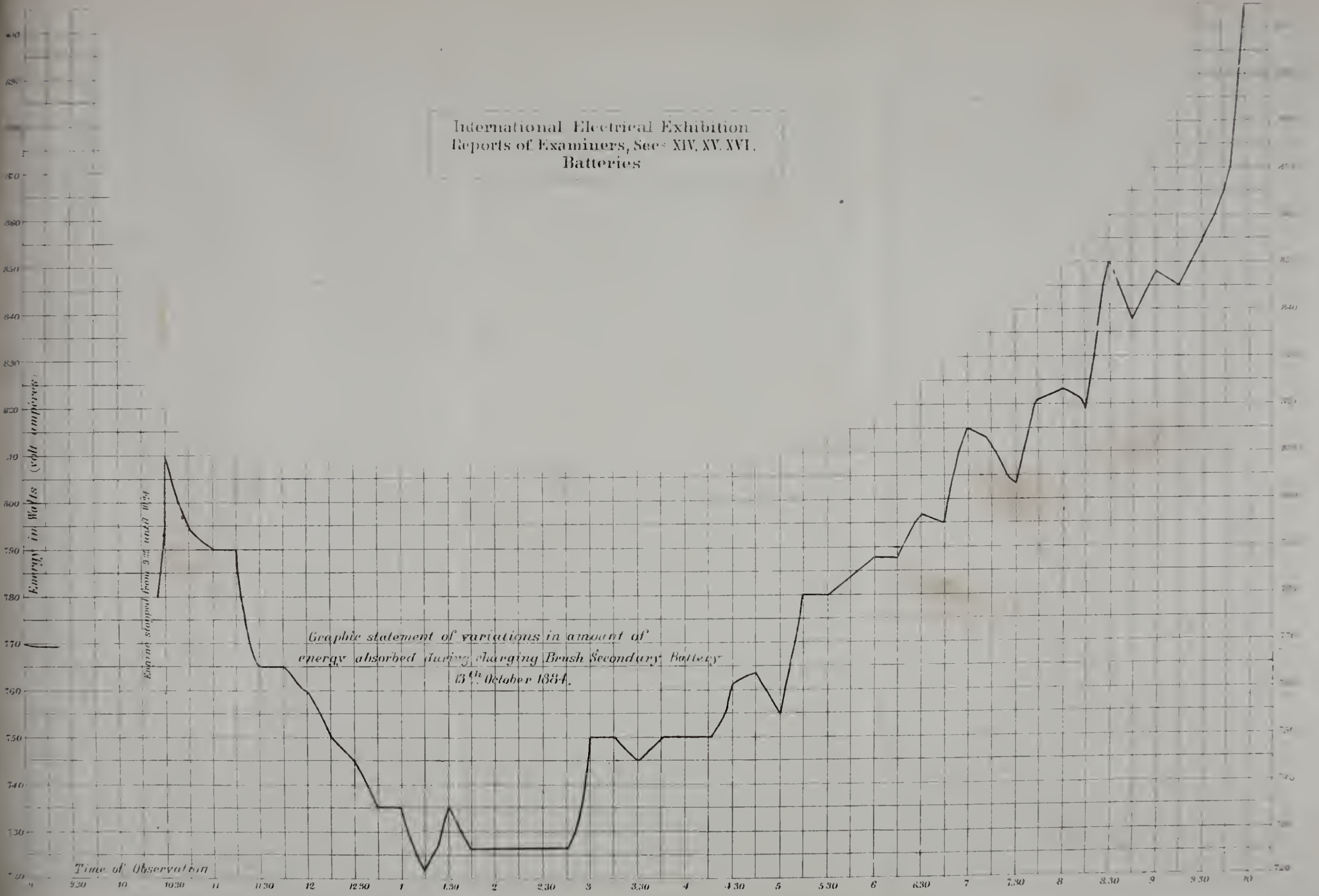
Adopted by the Section.

F. C. Van Dyck,
Chairman Section XIV.

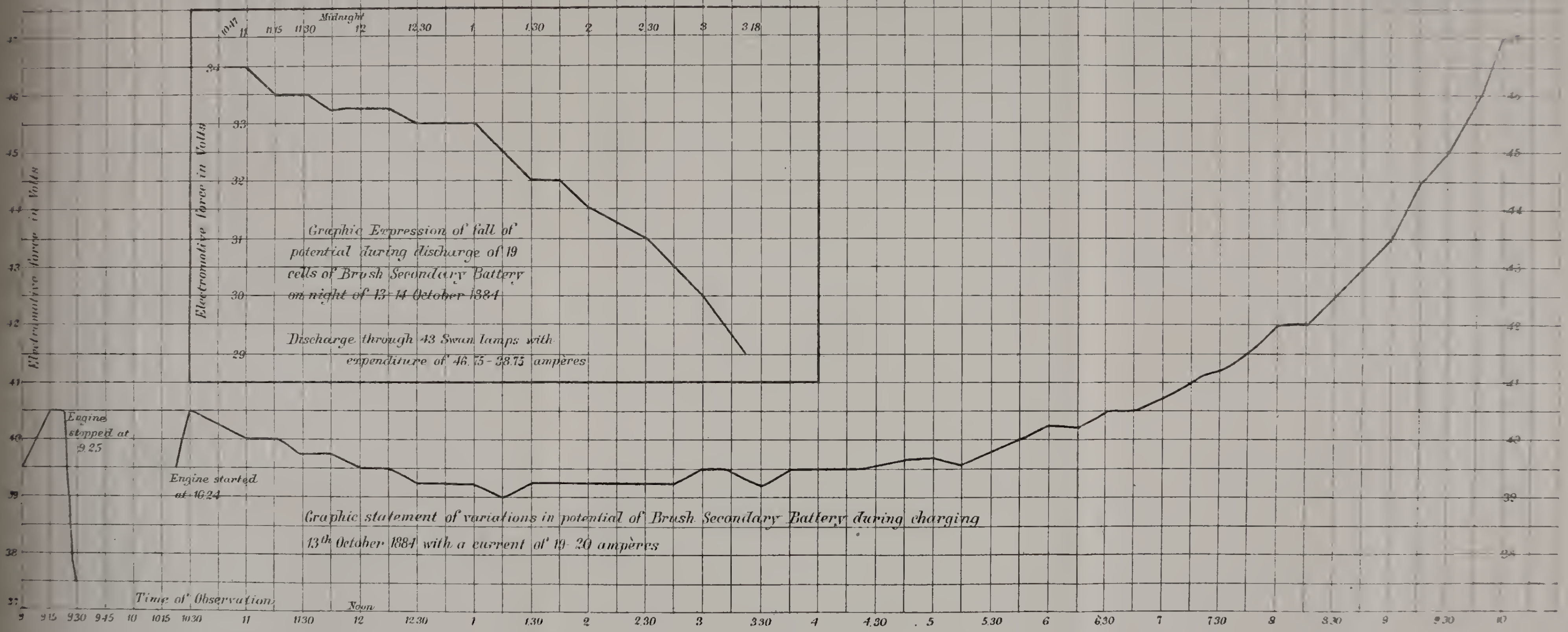
A. E. Dolbear,
Wm. Drysdale.
Samuel P. Sadtler,
Walter M. James,
William H. Wahl.

Wm. H. Greene,
Secretary Section XIV.

International Electrical Exhibition
Reports of Examiners, Sec^s XIV, XV, XVI.
Batteries



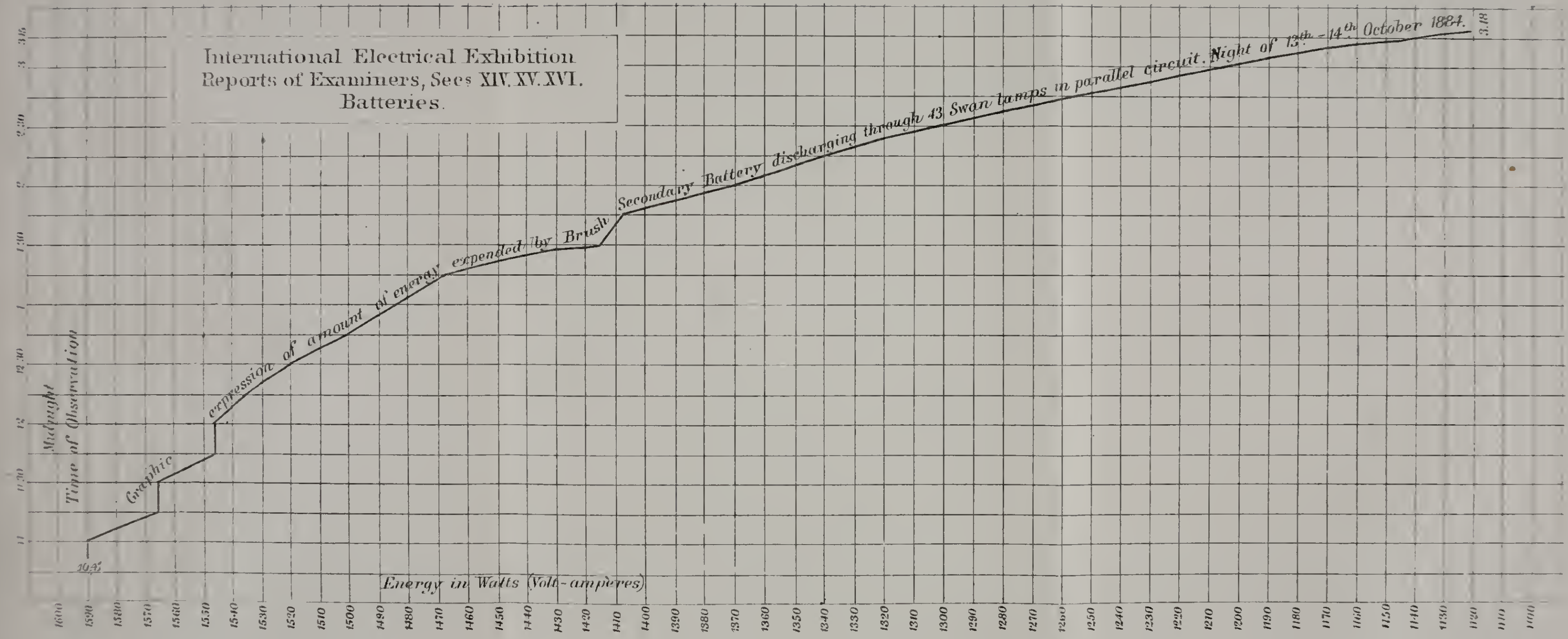
Graphic statement of variations in amount of energy absorbed during charging Brush Secondary Battery 13th October 1884.



Graphic Expression of fall of potential during discharge of 19 cells of Brush Secondary Battery on night of 13-14 October 1884

Discharge through 43 Swan lamps with expenditure of 46.75 - 38.75 ampères

Graphic statement of variations in potential of Brush Secondary Battery during charging 13th October 1884 with a current of 19-20 ampères



International Electrical Exhibition
Reports of Examiners, Secs XIV. XV. XVI.
Batteries.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXX.—MACHINERY AND MECHANICAL APPLIANCES.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXX, on Machinery and Mechanical Appliances.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXX (on Machinery and Mechanical Appliances), respectfully present the following report.

WASHINGTON JONES (*Ch'n*),
Examiners of Section XXX.

PHILADELPHIA, *December*, 1884.

MACHINERY AND MECHANICAL APPLIANCES.

The undersigned members of Section XXX, of the Board of Examiners, appointed to report on Machinery and Mechanical Appliances, would submit the following:

Since it was quite impossible and perhaps under the circumstances not altogether desirable to attempt any tests of the exhibits referred to this section, the report is based on the evident merits of such as were seen in actual use at the exhibition, while in cases where the advantage of this ground of judgment was wanting, it is clear that little more than passing reference to them could be made.

The Chambers Brothers & Co., of Philadelphia, exhibited a brick-making machine, with electrical counter attachment. Though the only electrical part of this machine is the counter, some other useful features are present deserving notice. The clay is tempered and moved slowly forward by knives revolving in a conical chamber of chilled iron, from which it is forced through a rectangular die by a screw fixed to the end of the same shaft which carries the tempering knives. Passing then through a sand-box the clay bar travels on an endless belt to the cutter, which consists of a set of radial arms on the end of a horizontal shaft, each arm having a wire stretched across its forked extremity, parallel to the shaft. Each wire as it is carried around this shaft cuts a brick from the sand coated bar of clay, the motion of the shaft being so adjusted to that of the clay bar by an ingenious arrangement of cams, that the bricks are formed with true, square ends and of uniform lengths. The practicability of this cutting attachment has been fully shown during the exhibition, the machine having made in that time about a million full sized bricks of tempered clay, with sanded surfaces. The whole number of bricks made was duly recorded by the electrical counting device, which was set up in a distant part of the building.

William Sellers & Co., of Philadelphia, exhibited a planer, lathe and geared drill press, in motion, by a Weston Electric Motor.

The Wicaco Screw and Machine Works, of Philadelphia, exhibited in operation a number of machines for the manufacture of screws and sundry small parts of machinery. These machines were designed and manufactured in their workshops, and embrace the most advanced ideas and appliances for this specialty, which add to the economy and quality of their products. They are of good design, well built and very complete.

The exhibit of Kelly & Co., Philadelphia, dealers in machine tools and supplies, consisted of a Jones & Lamson lathe and large screw machine for heavy work; an E. E. Garvin index milling machine, drill press and grinders; also one Stiles & Parker punch press. These tools are of the ordinary kind, sold by various makers and appear to be well made and adapted for the purposes intended.

The Taper-Sleeve Pulley Works, of Erie, Pa., exhibited several taper-sleeve wood pulleys, three friction-clutch pulleys, a dead pulley and a wooden pulley in halves. The taper-sleeve wood pulley has an iron hub with conical bore, into which fits a split taper sleeve or bushing bored straight to size of shaft. By a large nut on its smaller end, this sleeve is drawn into the hub and its consequent contraction on the shaft secures the pulley in place.

The wooden friction-clutch pulley, consists of a wooden loose pulley having an annular iron flange secured within its rim, projecting toward the shaft. The outer face of this flange bears against the ends of a heavy iron cross-piece, the two arms of which are bolted together rigidly on the shaft. Each of these arms carries two iron levers, the first, inside, next the pulley, has one end, hinged near the shaft, while the other bears against the inner face of the flange. The second lever, which is on the outside, and connected with the first by a bolt passing through the cross-piece, has its fulcrum at the end of the latter, while it carries on its end next the shaft, a cam, which when turned, draws the inner lever toward the cross-piece by means of the bolt, compressing between them a rubber spring placed on the latter.

The two cams have each a projecting arm lying close along opposite sides of the shaft, and a cone sliding on the shaft by a hand lever, separates these, thus turning the cams enough to cause the flange on the pulley to be gripped as in a vise. The gripping jaws are faced with maple wood, which makes them more durable and effective, and easy to repair. The wooden pulley in halves is built up on a web of narrow sectors of wood with the grain running radially, and is provided with an iron hub in halves secured by four bolts. The web is furnished with dowels, and two pairs of clamps bolted through it, form a substantial locking device near the rim.

The dead pulley—also of wood— is designed to facilitate the starting and shifting of a belt when the loose pulley is on the driving shaft.

On a hanger adjoining the pulley is carried a rope wheel concentric with the shaft and turned by the same rope which moves the belt shifter.

By a partial rotation of this wheel, a cam operates two sliding pieces, so that they bear against the loose pulley and press its rim against that of the fast pulley. The loose pulley is thus temporarily coupled to the shaft by friction, and the belt can now be shifted. By a reverse pull of the rope, which for a little way runs freely through the belt shifter, the rope wheel is again turned, removing the pressure and releasing the loose pulley from its hold, and by a still further pull the belt is shifted back again.

Alexander Brothers, of Philadelphia, Pa., exhibit a number of rolls of belting, ranging from 2 to 40 inches in width. They are all oak tanned, of good quality and of uniform thickness and texture. A 34-inch belt transmitting power from the Buckeye Engine, of the Kensington Works, ran very straight with a good contact on the pulleys.

The several rolls of belting exhibited by Charles A. Schieren & Co., of Philadelphia, Pa., from 2 to 5 inches wide, single and double, are of a dark color, owing to a special dressing used in their manufacture, which is claimed to give the belting great pliability, and to make it water-proof as well. That examined was found very pliable with a firm surface texture. Three double belts, a 30-inch, connecting the Porter-Allen Engine with the shafting, and two 18-inches, connecting the latter with a pair of counter-shafts, ran straight and smooth with good bearing.

An investigation of the exhibit of the Shultz Belting Co., of Philadelphia, Pa., showed a peculiarity in the manner of tanning, by which only the surfaces of the belt are oak-tanned, while the interior is only partly so, thereby retaining the properties of raw-hide to a certain degree. By a subsequent mechanical operatien, the requisite pliability is imparted. The belting examined was very soft and pliable, appearing to possess all the qualities of a good article. Four two-ply belts of this description, 8 inches wide, connected the two "Straight Line" engines with the shafting and showed good running and bearing. Two single belts, respectively 1 inch and $\frac{3}{4}$ inch in width, ran two of the Ball Dynamos and gave good satisfaction.

Messrs. J. H. Billington & Co., of Philadelphia, Pa., had an exhibit of Hoyt & Brothers belting which presented a fine appearance, though none of it was seen in operation.

The Ajax Metal Co., of Philadelphia, Pa., exhibited a metal showing a close, fine, grain, and apparently well adapted to meet the ends for which it is made. A car-wheel journal-box which claims to have had a run of 70,000 miles, presented a good appearance.

The Phosphor-Bronze Smelting Co., Limited, of Philadelphia, exhibited specimens of several grades of metal intended for widely different purposes, as for instance, gear-wheels, journal-boxes, wire, small fittings of various kinds, and also a sheet metal to meet a variety of requiremnets in making electric machinery.

Riehlé Bros., of Philadelphia, Pa., manufacturers of weighing and testing machines, exhibited several of their machines as follows: A light hand machine for testing samples of wire up to 1,000 pounds. The wire is held vertically and stretched by a screw and hand-wheel below the frame, a horizontal scale beam above, serving to weigh the strain. A heavier power machine, the general appearance of the frame being not unlike that of an ordinary lathe, intended for testing single specimens of wire, etc., ranging from a few inches to several feet in length, up to 10,000 pounds strain, The pull is obtained by a back-geared screw run by belt and pulley, and the test-piece held by suitable jaws, transfers the strain to the shorter vertical arm of a bell-crank lever at the other end of the machine, the longer arm of which, extending horizontally along the whole length of the frame, acts on the scale beam placed above, in the usual way.

The third machine exhibited was much larger than the other two, and is operated by a horizontal hydraulic plunger and cylinder, connected with a power pump and accumulator. It is a multiple machine that is intended for stretching and straightening several very long pieces of wire at one operation. For this purpose it is arranged so that the frame and foundation, carrying the straining-head, can be erected 50 or 100 feet, or any desired distance, from the mechanism for holding the other ends of the wires, and weighing the strain applied. The jaws at both ends are arranged to grip from one to six wires at once, a feature of some value for wire mills where it may be desired to carry on such operations with rapidity.

As no arrangements were made to exhibit the working of these machines, it can only be said that they seemed to be well adapted for the work they were intended to do.

The "M. T. Davidson Steam Pumps" exhibited are known as "Heavy Pressure or Boiler Feed Pumps."

It is to be regretted that these pumps were not subjected to systematic trial that a complete report of their performance and merits might be written. They, however, possess many points of excellence which are apparent without extended trial, and which may be thus enumerated.

Uniform velocity of water piston and delivery, under ordinary conditions of supply or suction. The speed may be controlled to any degree of nicety desirable.

The water end, its valves, passageways and piston are admirably arranged for readiness of access and economical working. The small number of working parts must greatly lessen the frequency of adjustment and repair. Lightness, compactness, stiffness and strength are qualities secured by the absence of complicated gearing, and the advantageous position of the frame uniting the steam and water ends.

It should be added, that these pumps are specially adopted to land service, where their highest economy and efficiency would be realized.

The "Chalmers and Spence Pipe Covering," used on all steam pipes in the exhibition building, gave entire satisfaction when first applied, but soon became so charred by the heat of the steam used—about 331° F.—as to be, in a measure, ineffective.

"Burgess' Patent Portable Mechanical Blow-pipes" fulfill all the requirements of the ordinary blow-pipe, and are applicable to a far wider range of work in brazing, soldering, tests and analyses.

The blast supplied is steady, and completely within the control of the operator. Its use admits of the free manipulation of the flame, and object operated upon. It is handy, compact and durable.

The Metallic Gaskets of the "Common Sense Packing Manufacturing Company," employed generally throughout the exhibition building in making the joints of the numerous steam and water-pipes, gave entire satisfaction.

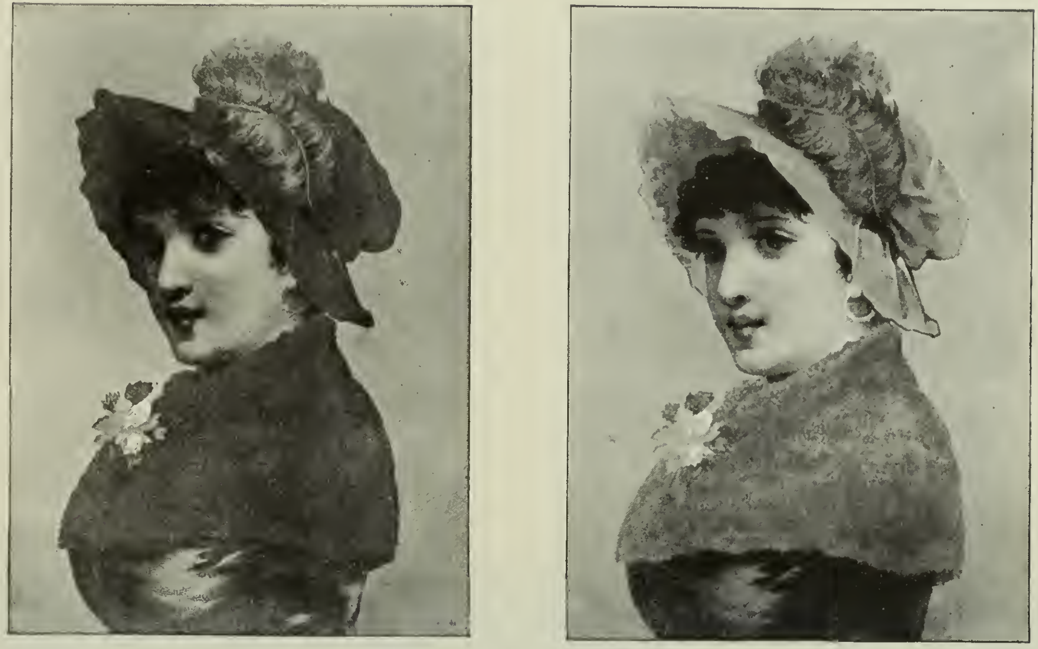
The metal of which these gaskets are made, would seem to be superior to rubber for steam and water joints, enduring a greater degree of heat without deterioration. They can not be blown out by ordinary pressure, are not effected by contact with water or steam, and posseses sufficient elasticity to withstand ordinary shocks and vibrations.

A variety of these gaskets is specially prepared for flanged joints, which from any cause come together imperfectly, and it is believed will meet a long felt want in steam and water-pipe fitting. The packing proper, of this company, specimens of which were exhibited—and of which a wide range of sizes are manufactured—is designed, mainly for piston rod and valve stem packing, and for such purposes we take pleasure in recommending its use. R. C.

Adopted by the Section:

WASHINGTON JONES, *Chairman.*
C. W. SCRIBNER, *Secretary,*

C. CHABOT,
G. MORGAN ELDRIDGE,
ROBERT E. CRAWFORD,
JABEZ H. GILL,
HUGO BILGRAM.
LUTHER L. CHENEY,
CHARLES E. RONALDSON.



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From Isochromatic Photograph.

IVES' PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884
OF THE
FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,
FOR THE
PROMOTION OF THE MECHANIC ARTS

REPORT OF EXAMINERS

—OF—

SECTION XVIII.

(SECTION II., CLASS IV. OF THE CATALOGUE.)

UNDERGROUND CONDUITS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, FEBRUARY, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman.*
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XVIII.—UNDERGROUND CONDUITS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XVIII, on Underground Conduits.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The following report of the Examiners in Section XVIII (on Underground Conduits), is respectfully submitted.

F. D. DE WOLSKI (*Ch'n*),
Examiners of Section XVIII.

PREFACE.

In submitting a report on the various underground conduits exhibited at the International Electric Exhibition the undersigned Examiners desire to mention that their task would have been a much easier one had each exhibitor furnished them at the outset with a brief practical description of his system. In fact few of them did themselves justice in this respect.

The undersigned carefully examined the models, in the presence, as far as possible, of the exhibitors themselves, and some of the members inspected the systems in practical operation in the city of Philadelphia. They regret they were unable to carry out any system of tests owing to want of time and absence of facilities.

A programme was drawn up by Dr. Frazer, and approved by the Section, to assist the examiners in framing their individual reports on each system, and will be found attached to this report.

Although the examiners abstained as far as possible from entering into the comparative merits of the systems, the examiners considered it advisable to note the obvious merits and demerits of each system, so far as they had means of judging. The points upon which they have commented are such as a sufficient experience of analagous contrivances enabled them to judge of from the bare statements and descriptions. In no case was it possible to state from actual observation of the working of any of these systems, that they did or did not fulfil what was claimed for them.

Your examiners are of the opinion that during the experimental stage of underground conduit construction for electric currents, it is desirable, in the interest of the community in which such conduits are laid, that the latter be capable of use for as many different purposes, and by as many different companies as possible: and also be capable of inspection in every part, and removal or replacement with the greatest possible rapidity, and the least possible obstruction to the public highways.

The rapid advance of electrical science in the past renders it nearly certain that the next few years will witness great changes in the methods for the production and distribution of this form of energy; and with an unelastic system in which a corporation may have expended large sums of money, the practical advantages of the introduction of electricity may be entirely dissipated for a long time. For the same reason it seems to the undersigned unadvisable at the present time for a corporation to adopt any style of plant which is adapted only to one system of distribution, however excellent the system may seem to be.

They feel impelled to add one final word in view of the doubt that has been expressed as to the feasibility of constructing underground conduits for all purposes of electrical distribution. Certainly, at least, within the limits of large cities, whether or not it be found in the future to be desirable to enclose telephone and telegraph, with light and power circuits; or any two of the foregoing in the same conduit, they express no opinion, but that the electric current for any and all of these purposes can be successfully transmitted underground, there is not the least reason to question.

They believe that a careful series of tests, made by competent experts, on the systems already laid, would be of great value to science, and to all those who are interested in the use of the electric current.

ALPHABETICAL LIST OF THE EXHIBITS VISITED BY THE COMMITTEE.

(SECTION XVIII.)

The exhibits mentioned here do not include all of those mentioned in Section II., Class IV. of the catalogue. Some of these latter do not properly belong to the "underground" class; some of them were not found by the committee, and some had no one to explain them, and no printed or written descriptions which could be procured.

For one or more of these reasons the undersigned examiners have been obliged to omit mention of some exhibits which are classed in the catalogue under the head of Section II., Class IV.

(*Form of sheet with blanks prepared for the use of members of the Section.*)

INTERNATIONAL ELECTRICAL EXHIBITION
OF THE
FRANKLIN INSTITUTE,
September and October, 1884, at Philadelphia.

Programme for Examination, by Section XVIII. of the Board of Examiners,

IN SECTION II., CLASS IV.

OF THE CATALOGUE.

(UNDERGROUND CONDUITS FOR ELECTRIC CONDUCTORS.)

DIVISION OF THE WHOLE SUBJECT.

A.—Advantage or disadvantage to those using currents.
  a. Electrodes permanently sealed.
  b. Electrodes capable of being inspected at every part.

B.—Advantage or disadvantage to the communities at large.
  1. In city streets.
  2. Adaptability for different companies to use in common.
  3. Relative supply.

C.—Systems undeveloped or partially developed.

Members of the Section are requested to fill up as many as possible of the blanks for as many as possible of the exhibits, and to forward their notes to the Chairman of the Section, Captain de Wolski, at the building.

HOW DO THE SEVERAL EXHIBITS STAND WITH RESPECT TO THE FOLLOWING PARTICULARS?

(a.)—Electrodes permanently sealed.
(b.)—Electrodes capable of being inspected at every part.
  1. Preservation of insulation.
  2. Expense of insulation per unit of length.

3. Avoidance of induction.

4. Speed of signalling; *i. e.*, capacity for rapidity of charge and discharge of conductor.

5. Cheapness of plant and maintenance.

6. Ease and cheapness of laying and taking up.

7. Facility for expansion. (Increase in number of conductors singly or by groups.)

8. Rapidity of repair.

9. Durability.

10. Safety of wires from stroke by lightning.

EXHIBITS OF UNDERGROUND CONDUITS FOR ELECTRICAL CONDUCTORS.

(From the Official Catalogue, page 79.)

Continental Underground Cable Co. Models of Underground Conduits. (No. 5, North Gallery.)

Woodward, Jas. S., Phila. Woodward's Curb Conduit for Electric Conductors and Steam Heating Pipes. (North Gallery.)

Hendley, Wm., Washington, D. C. Wooden Conduit for Electric Conductors. Water-color illustration of above conduit system. (East Gallery.)

American Underground Electric Wire Co., New York City. Howe system for insulating electric conductors and cables, applicable to underground systems. Apparatus for designating wires in conduit systems. (West Gallery.)

The Anderson Conduit. (North West Gallery.)

American Sectional Electric Underground Co., Phila., Pa. Underground conduits and man-holes with telegraph, telephone, and electric light and power wires, showing this system of underground conduits for electric wires in operation. (L. 11–15.)

Edison, Thos. A., New York. Samples of Underground Conducting System, employed by the Edison Company. (N. 3–6, S. 3, U. 6, A. 3–6, D. 3–6.)

The Edison Exhibit of the Combined Edison Companies, New York City. Edison System of Underground Electric Conductors, with junction boxes, couplings, etc. Insulating compound. Insulating tape. (See above.)

Brooks, David, Philadelphia, Pa. The Brooks System of Underground Conduits for Electric Conductors. (Main Building, U. 14.)

National Underground Electric Co., of Newark, N. J. Full-sized model of the Conduit for Telegraph, Telephone and Light Wires, with testing station, etc. (Depot South Porch.)

Cosmopolitan Underground Telegraph, Telephone, and Electric Light Co., Camden, N. J. (Annex.)

Continental Underground Cable Co., Camden, N. J. System of underground conduits for electric conductors, including electric railway through centre of conduit for transmission of mail, packages, etc. Pipe System of Underground Conduits. (Annex.)

Union Electric Underground Co., Chicago, Ill. Conduit for Electric Light, Telegraph and Telephone Wires. Insulation and ground connection for wires. Machines for introducing wire into insulating tube. (Depot, N. Porch.)

THE AMERICAN SECTIONAL UNDERGROUND COMPANY.

(*" A. b." of Section's Classification.*)

This system consists of cast iron conduits, built up in sections break ing joints; the joints being secured with clamps and keys, and cement or other packing. All parts of each particular size are interchangeable. The conduit contains interchangeable metallic shelves and partitions, dividing it into compartments for carrying wires of different kinds.

Three sizes of conduit were exhibited, each being connected to a manhole placed at every street corner, into which one or more men can enter for the purpose of hauling in the wires, making the necessary connections, etc. There are further, at convenient distances along the line of conduit, handholes for tapping the wires for house-to-house supply. As the position of these is accurately known, by opening up a few stones in the pavement a wire or wires can be tapped for house supply. This is effected by running the wires required from the nearest manhole on the upper or local shelves.

Different companies can be supplied with separate compartments, and they can employ any particular insulation they prefer.

It is claimed for this system that " a metallic contact between the insulation of all wires and the earth grounds all leaking or induced currents, overcomes induction to a great extent, and renders harmless a cross in an electric light current. Further, that by the use of the copper shelves, in conjunction with telephones on metallic circuits, there is absolutely no interference whatever."

The committee was unable to satisfy itself on all these points.

The conduit when opened appeared to be very dry. It is stated that all condensation of moisture in the conduit takes place only under the manhole covers, which are exposed to the external air. This seems to be borne out by observations on the 9th of October, 1884, no rust being visible.

This system seems to meet, in a very complete way, the question of house-to-house supply; separation of wires; facility of laying; repairs; and future expansion. It is not necessary to lay the wires in the conduit until absolutely required. It would, however, be necessary to use first-class insulated wires, as it would not be possible to keep such a conduit absolutely dry. Some provision will also have to be made for passing off gas, which tends to accumulate in the main, and might be set on fire and prove dangerous. It is estimated that the *A* conduit, 10 inches by 15 inches, would cost $15,000 per mile, the *B* conduit, 6 inches by 10 inches, $10,000, and the *C* conduit, 5 inches by 8 inches, $5,000. The *A* size of conduit, which is laid in Chestnut street, Philadelphia, from Third to Broad (equivalent to Fourteenth) streets—(about a mile in length)—is estimated to accommodate 3,000 wires. The *B* size is laid in Tenth, Eleventh and Brown streets, and its capacity is for about 1,200 wires.

By means of the large manholes and separate compartments, the wires in use can be at any time taken out, replaced by others, or inspected and put back, in the shortest time and with no derangement to the pavements and streets. The size of the conduit also enables one to lay a very large number of wires. The prevention of induction would seem to be about equal to that in all systems employing iron-cased ducts, with the additional advantage of interior metallic screws and copper shelves, all well grounded, so that no current in one compartment would be likely to have any influence on those of another.

The conduits were laid down along Chestnut street in October, 1883, and the electric light service has been continuous since the latter part of December of that year, which period included a number of severe storms, of longer or shorter duration.

It has not been ascertained that any interference with the service has been suffered. The weather during the continuance of the exhibition was unusually dry, and, therefore, though the interior of the conduits was dry wherever seen by the examiners, this would not establish the fact of the successful exclusion of moisture by this system under unfavorable circumstances. On this point the undersigned have been compelled to take the testimony of the officers of the company and the statements of the subscribers as to the success of the conduits for the electric light wires.

Few, if any, telegraph or telephone wires were in the conduits, and as it is with these that the defects of any system would be best observed, the examiners have no sufficient data for expressing an opinion.

It is the intention to introduce these insulated telegraph and telephone wires loosely, or without any casing, unless there be a long distance in which no service is ever to be made. Under these circumstances the company proposes to use a cable. Otherwise, the wires are to be laid loosely over each other in their various compartments.

A question which is intimately connected with the conduit itself is that relating to the exclusion from it of foreign matter, and especially of water. [The company has suffered from gas in its conduits, and on one occasion an explosion ensued in a manhole near the State House, but this latter caused no serious damage, and it is not thought likely that there are many localities where these conditions of gas waste under the streets are likely to be similar.]*

In the streets of a city where there were great differences of level, any considerable break in the conduits which would permit the influx of a large body of water might (if the latter found free path) do considerable damage. This is an objection applicable to all hollow conduit systems.

Open gratings have been employed to permit the waste gas to dissipate itself, and these gratings have often remained open during both snow and rain storms without introducing moisture into the main conduits, the water escaping by a trap at the bottom of the manhole.

So far as the renters of the light are concerned there is not the least danger of the introduction into their houses of water or gas from this company's conduit, inasmuch as the electrodes are hermetically sealed in a gas pipe which leads them from the handhole.

A telephone wire is laid down in the conduits, leading from the company's central office, in Eleventh street, to Broad and Chestnut streets corner. This was tested in the daytime, when the electric light currents were not passing. The terminal instruments were also out of order. The committee cannot, therefore, say what may be the effect of the electric light current on the telephone lines from this observation.

The following is a description of the figures in the cut:

Fig. 1 represents a longitudinal elevation of various sizes of conduit *A*, *B*, *C*, with vertical sections through "manhole," *d*, *e*, *g*, and "flush box," *b*, showing mode of laying and connecting them.

Fig. 2, plan view of same.

Fig. 3, isometrical view of section of *A*, conduit, and hand-hole, *c*, *j*, showing joints of upper and lower sections of conduit, *K*, *K*, partitions and shelves for electric wires, the "static condensing shelves" being shown by dotted lines.

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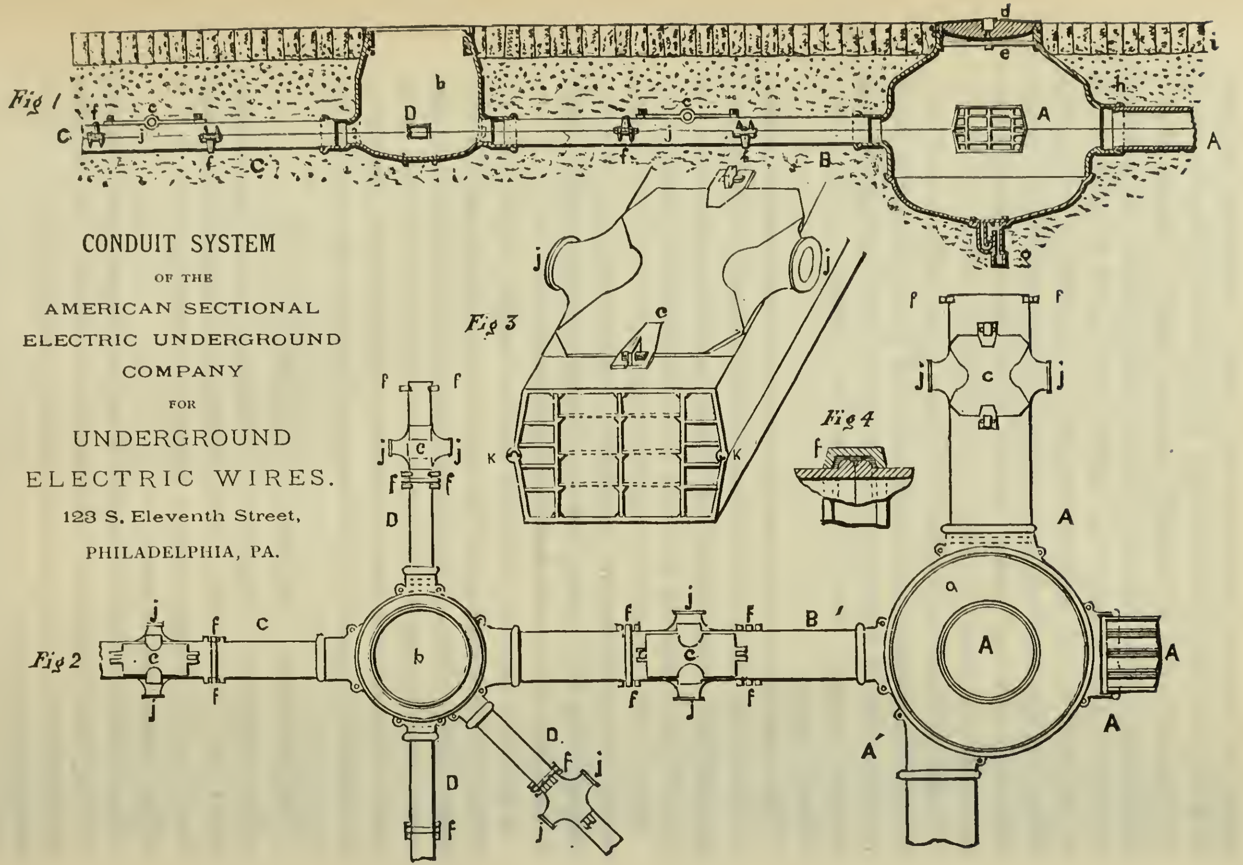
* This report was completed on October 30, 1884.



CONDUIT SYSTEM

OF THE

AMERICAN SECTIONAL
ELECTRIC UNDERGROUND
COMPANY

FOR

UNDERGROUND
ELECTRIC WIRES.

123 S. Eleventh Street,
PHILADELPHIA, PA.

Fig. 4, tranverse section through top of clamp, showing section of ends of conduit and packing at joints.

The letters show similar parts in the different figures, *A* being the largest size conduit yet made, capacity about 3,000 wires. *A′*, showing the conduit opening in manhole when connection is made at one side of manhole or flush-box. *B*, *C* and *D* are consecutively smaller sizes of conduit; *a*, manhole, *b*, flush-box, *c*, handhole, *d*, manhole and flush-box cover made either solid, or perforated for ventilation; *e*, bar with which to fasten cover by aid of bolt and nut; *f*, clamp and keys by which the different sections of the conduit are connected; *g*, trap for drainage of any water which may collect in the manholes and flush-boxes from rain or condensation, and which may be connected with sewer; *h*, street-bed, earth and gravel; *i*, street paving; *j*, handhole opening for house connections; *k*, longitudinal joints between upper and lower sections of conduit, to be filled with any suitable packing to exclude moisture, etc.

THE ANDERSON CONDUIT FOR UNDERGROUND WIRES.*

("C." of Section's Classification.)

This conduit is constructed of cellular section and of any suitable material, such as iron, terra cotta or glass. It provides a series of ducts, into which cables or wires of different classes or belonging to different subscribers, may be accommodated. In both sides of the conduit are a series of lateral openings, formed in the process of manufacture of each length of the conduit. These openings give access to the ducts on either side, and are intended for tapping the wires at any desired point. Each side duct, on either side of the conduit, has one of these lateral openings, which are not arranged one over the other, but diagonally and in adverse directions on either side. The object of this arrangement, which appears to be the main feature of the system, is to obviate the weakening of the structure, which would result from having a row of openings one above the other.

No provision is made for manholes, and no arrangements are proposed for obviating the effects of induction, nor for keeping the duct water-tight or free from condensation.

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* Patent No. 261,979, dated August 1st, 1882.

The description and model were not sufficiently complete to enable the committee to form any opinion of the details, but the provision of a lateral opening to each side duct would have many disadvantages.

THE BROOKS UNDERGROUND CONDUIT.

("A. a." of Section's Classification.)

This conduit consists of wrought iron pipes, supplied with suitable splice-boxes, hand-holes and outlets. These pipes are protected from oxidation by being laid in a wooden trough, into which hot pitch is poured so as to completely envelope the pipe. The wires to be used in this system are covered with cotton and formed into a rope or bundle, which is then covered with a textile weaving. The bundle of wires is then soaked in hot mineral oil and drawn in long lengths into the pipe or conduit. A heavy mineral oil is then forced into the pipe so as to exclude moisture, and for the purpose of maintaining a good insulation.

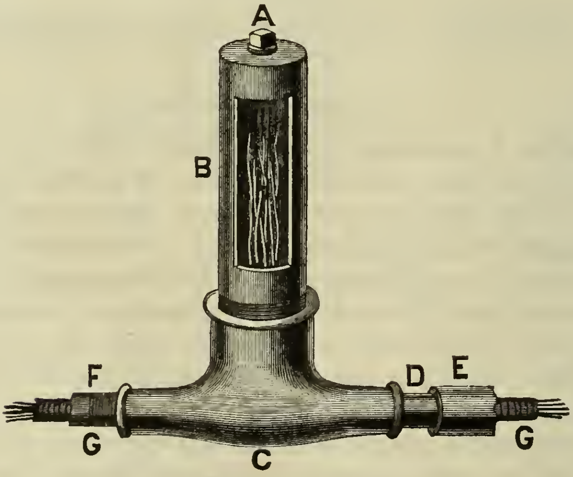


FIG. 1.—Method of making splices.

The patentee estimates the cost of laying a 2½ inch pipe complete, for house-to-house supply, with 40 conductors of No. 16, *B. W. G.* and 360 of No. 20, *B. W. G.*, at twenty dollars per mile per conductor. He states that he can lay such a conduit in one day, from block to block, so that its construction causes but little interference to traffic.

The main point of the system, is the economy of insulation. It is

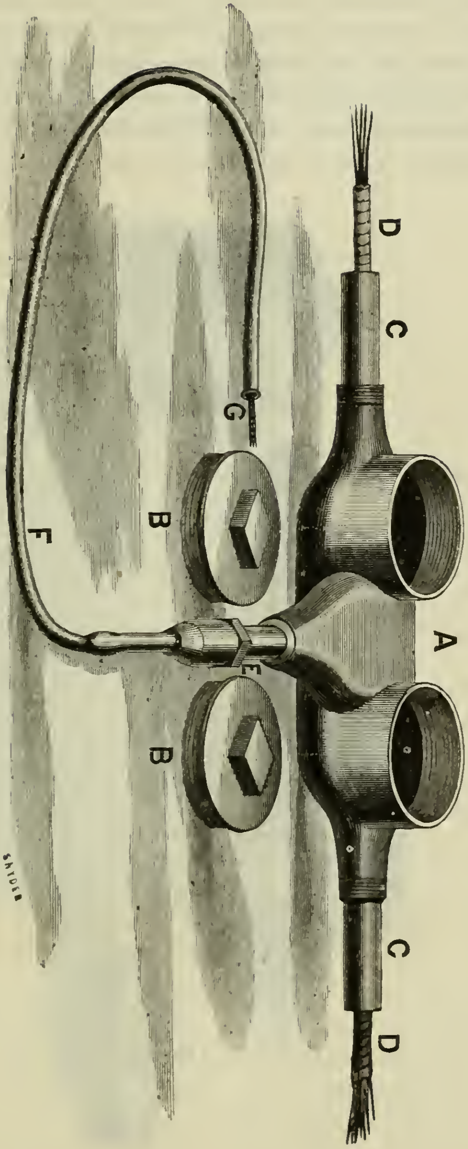


FIG. 2.

proposed to anticipate future requirements by laying down as many wires as may be required for a long time to come, and not to add or withdraw any. It is a system which seems better adapted for trunk or through lines than for house-to-house supply, owing to the difficulty that would be experienced with the overflow of oil at so many points. In towns where there was much difference of level the head of oil would doubtless be a source of great trouble.

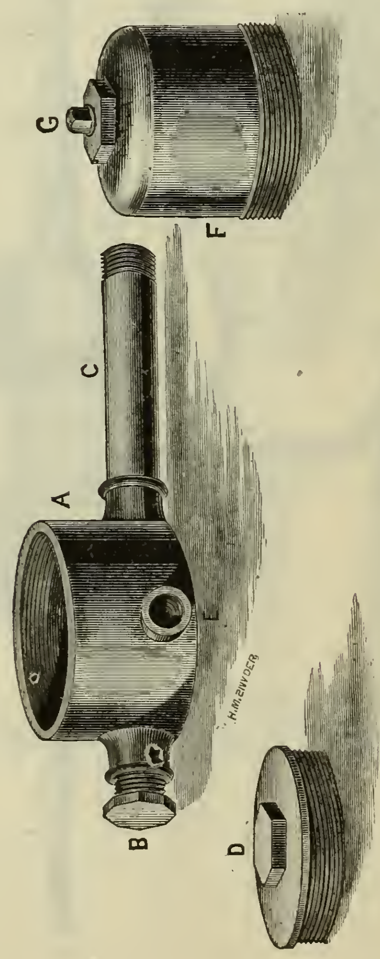


FIG. 3.

Fig. 2 shows the handholes and outlets for taking wires into adjoining buildings. *F*, is a piece of lead pipe, of any desired length, sufficient to reach the first story of the building in which the wires are to be extended or looped. The lead pipe, *F*, is filled with a heavy and viscid oil until it reaches within two feet of the point *G*, where it is spliced to india-rubber or gutta-percha covered wires. The space between the gutta-percha covered wires and the lead tube is filled with plaster of Paris and silicate of soda, which effectually prevents any leakage of the oil.

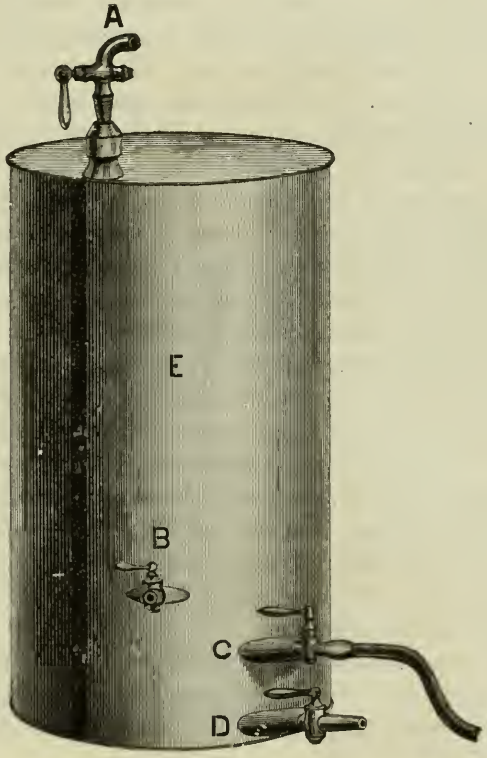


Fig. 4.

Fig. 3 shows a splice-box, hand-hole and outlet on both sides, designed to accommodate 400 wires. *C*, is a two and one-half inch diameter pipe. Reducing sockets can be introduced at *B*, for a smaller pipe and less number of wires. These boxes are introduced at intervals, fastened with plug, *D*, for bringing out the wires. The box is seven inches in diameter inside. When used for splicing the ends of the cable, dome *F* is screwed into the top of the box. *G*, is a plug in the top of the dome for pouring in oil after the splice is made. On either side of this box is outlet *E*, similar to that shown in Fig. 2.

Fig. 4 shows the tank at the Pennsylvania R. R. Station, Broad Street, Philadelphia, supplying the system with pressure and the oil lost by leakage (which is not perceptible).

As regards the efficacy of the oil, as a means of insulation, Mr. Brooks exhibited to the examiners this experiment: Two wires were attached to the Holtz machine, the extremities being carried into a narrow jar of his insulating oil, in such a manner that while the distance between them was ¼ inch in the oil, they were 1½ inches apart at the surface of the oil. On turning the machine, the spark passed above the surface of the oil, and not at all through the oil, even when the distance between the extremities was reduced to $\frac{1}{16}$ inch. A number of experiments were made as to the effect of the Brooks system in reducing induction and other disturbing elements; various circuits having been politely put at the examiners' disposition for this purpose in the Pennsylvania Railroad building.

One of these was a line through a Brooks conduit to the Broad Street Station, and a return through the earth. This line gave a considerable amount of disturbance, the noise being rather deep than loud, and reminding one of visible movement. The voice was carried clear and distinct. A second Brooks circuit was metallic, *i. e.*, the message went and returned by wire, the distance between the station being about 1¼ miles. The crackling noise was audible, but not loud or deep. A line to Merion Station and return, by overhead wire (14 miles), worked nearly as well. The crackling was *finer*, *i. e.*, shriller and more continuous, but not so disturbing.

No means were available for testing the amount of interference with each other of the several wires of telegraphic and telephonic circuits in the same tube, worked simultaneously. 2,000 feet of wire is pulled through each length at a time.

THE CONTINENTAL UNDERGROUND CABLE CO.

(*"A. b." of the Section's Classification.*)

Description by the Company, edited by the Examiners undersigned.

This company's plans consist of two distinct systems. The first is described in figures 1, 2, 3, 4 and 5, and the second is described in figures 6, 7, 8 and 9. While it is here described more particularly as an electric lighting system, it can as advantageously be applied to wires for other uses of electricity, and is adapted to cross streets, or where one company wishes its own separate conduit. The first-mentioned system being the trunk line system, to accommodate all the different companies in one plant.

In the trunk line system the conduits are constructed with a view of keeping the dampness from penetrating them by either making the walls of asphalt or asphalt blocks (or other anti-moisture material); or by constructing the walls of bricks laid with cement mortar and covering the outside of the wall with asphalt or cement to keep the moisture out, and then keeping them constantly under pressure of dry air.

In order to use a comparatively cheap cable, the conduits are kept dry for the protection and preservation of the cables. And further, they are kept under pressure, and objectionable gases are kept excluded, as dampness or gases will not enter against inside pressure.

At first sight it may be said that there will be considerable cost attending the process of pumping dry air into the conduits, but a conduit of one, two, or three miles in length, may be kept under pressure by a very slight power from a single pump, which may be rented anywhere along the line and connection made to the conduits at a very small yearly cost to the company in conformity with the plan in the patent.

Every electric light company having an engine running to compress the air supplied at the generating station for the tubes containing their own wires, as shown in Fig. 6. The principal object in keeping the wires and conduits under dry air pressure is to prevent the escape of electricity from the wires, or reduce the escape to a minimum. While this principle is adapted to telegraph and telephone wires, it is particularly adapted to underground electric light wires, where very heavy currents are passed; for on long circuits the lights on the farthest end of the line or circuit burn dimly and are incapable of giving that brilliancy of illumination for which they are designed, unless the intensity of the electric current is greatly increased over the normal, and this is injurious to the lamps near dynamo electric machines and requires a greatly increased expenditure of power used in the generation of the current. By the use of the means employed by this company to retain the full force of the electric current, it is claimed that the distant lamps burn as brilliantly as those near the generators, and all burn with a maximum brilliancy without increasing the intensity of the current over the normal, and with a minimum expenditure of power. The accomplishment of this result depends mainly upon two phenomena, viz., the absorption of the moisture from within the conduits, by chemically dried air (the moisture rendering the air a good conductor), and increasing the pressure or density of the air around the conductors and within the conduit, by mechanical means, the same preventing the free escape of electricity from the wires.

The conduit should be made practically air-tight, with an air compressor at one end adapted to constantly force air into said conduit under pressure, and apparatus to contain an absorbent for the extraction of the moisture from said compressed air, and an escape or pressure valve adapted to remain closed until the desired pressure of air is obtained, and attached to the conduit at its other end or at different places along the conduit, and when the air compressor is put in motion to force a constant current of air under pressure into the main and out through said relief valves, and thereby insure a perfect circulation of chemically dry air under pressure.

The greater the pressure or more dense the atmosphere, and the more free the air is from moisture; the less liability is there for the escape of electricity, and *vice versa*, to follow a natural law which has been demonstrated, the more rarefied the air around an electric wire and the more moisture it contains, the more freely will electricity escape from the wire. By this process every part of the space within the conduit (not occupied by the wires or their covering) will be occupied by compressed or dense dry air. The insulation should be perfect, as there will be no space so small that the compressed air will not instantly penetrate it. In the case of electric light wires, they will be supported within a tube by glass or porcelain supports, as represented in figures 7 and 8, and each wire having an air space surrounding it, the dry compressed air will encircle each wire and insulate it perfectly from all others. A slight insulating covering as an extra precaution should be used on the electric light wires also.

One of the simplest forms, system No. 1, is shown in Fig. 1. A conduit for one or more cables of wires is arranged on either side of the track to accommodate, combined, 800 wires.

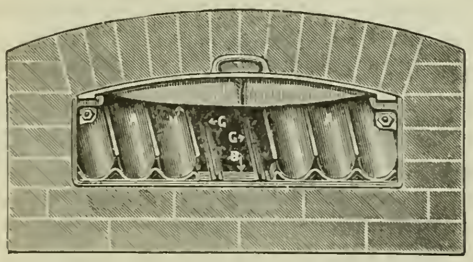


Fig. 1.—Inside measurement, 4½ x 17 inches. Capacity, 800 wires.

That shown in Fig. 1 will probably be sufficient for any one company for many years to come, but where more wires are required the capacity of Fig. 2 should be had, and any single company will probably never require on any street more accommodation for wires than can be had by the conduit shown in Fig. 1, but should a greater capacity be required, the construction shown in Fig. 2 may be used, in which it is seen that pockets are arranged in a manner similar to that shown in Fig. 1, but two deep. In place of arranging pockets as shown in Fig. 2, they may be arranged as shown in Fig. 3; in which the pockets are arranged in single rows, one above the other, four deep.

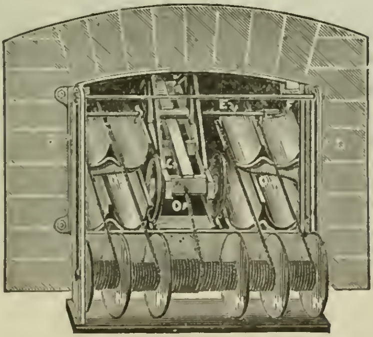


Fig. 2.—Inside measurement, 9 x 17 inches. Capacity, 1,600 wires.

Figs. 4 and 5 show the system for laying wires on a larger scale, and which is especially adapted to accommodate a number of separate companies. Each of said figures show the same capacity with but a slight difference in construction, the arms supporting the pockets in Fig. 4 uniting both uprights and a track is furnished to each apartment of six pockets; while in Fig. 5 the arms or brackets do not thus unite, but leave a vertical passage way from top to bottom of the conduit wherein the motor or carriage, running upon the rail of the bottom, causes its adjustable arms to travel when in the act of laying the cords, wires, or cables in the various pockets upon either side of said passage way. For an entire city only one motor and one carriage will be required, or if the process of laying the wires is to be carried on by either the carriage or motor alone, then the one or the other may be dispensed with; the pockets are made semi-cylindrical, three inches wide at the top and an inch and a half deep, or they may be made nearly cylindrical with a slot on the upper or top side running the whole length to admit of the chain or cord being laid in the pocket by the car with which to draw the cables into position. The space for the motor is between five and six inches wide, but reduced to two inches above the railway, and as it extends from the bottom to the top of the conduit, access to the

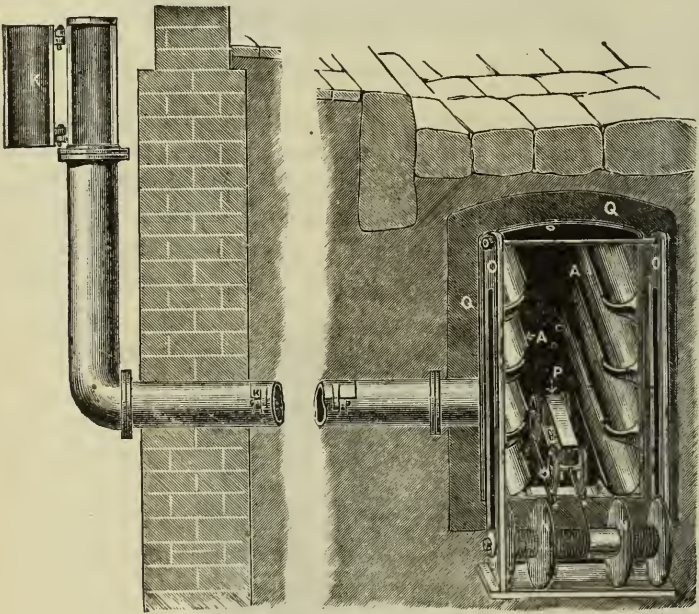


Fig. 3.—Inside measurement, 11 x 18 inches. Capacity, 1,600 wires.

cables without removing them from their pockets can be had from the top if at any time it should be desired or become necessary.

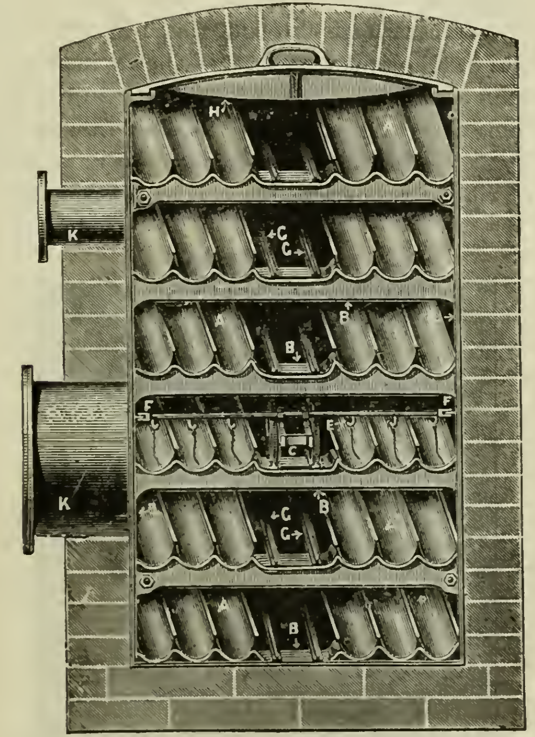


FIG. 4.—Inside measurement, 23 x 27 inches. Capacity, 7,200 wires.

A vertical space of one to two inches is left between the upper and lower pockets to enable the passage of the motor or carriage arm and also to enable the cable to be tapped and the wire taken through an outlet. (See *K*, Fig. 3.)

Service from the conduit to houses may be made by a connection run under the sidewalk and into the cellar, as shown in Fig. 3, conveying wires through said pipe into the houses. The conduit before each house is provided with a plugged branch, which may be opened for connection when required.

Where a number of companies are using the construction shown in Fig. 4, each of said companies can place a suitably arranged lock against admittance to their respective apartments.

Fig. 3 shows an electric motor in the act of drawing a cord or wire cable from a spool supported by an adjustable upright, temporarily placed in a manhole for the purpose; this cable when laid, being adapted to draw the carriage through, which in turn lays a series of cords or cables in the various pockets, as shown in Fig. 2. If it is required that the carriage make two or more trips successively, then the carriage, in being drawn through, may also draw through an additional cable (see Fig. 2), by which said carriage may be returned after laying the first lot of cords or electric cable, and be in readiness for a second supply

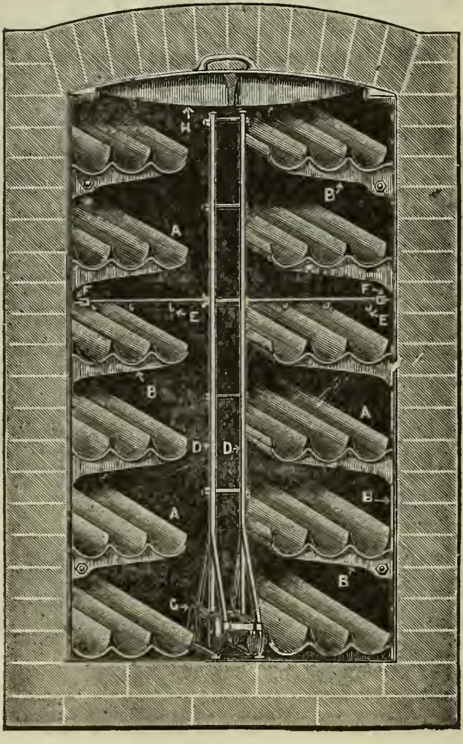


Fig. 5.—Inside measurement, 23 x 27 inches. Capacity, 7,200 wires.

The plan is to place the largest number of wires in the smallest possible space after allowing for space to conveniently get at the wires, lay and relay them, for taking them off to houses and for circulation of dry air, etc.

The walls of the conduit may be built of blocks made from asphalt compound, by an improved process, whereby it becomes impervious to moisture, and possesses great strength; and the metal uprights, brackets, and pockets, are connected with the earth to carry off induced electric currents to the earth. By this construction the conduit can be built more cheaply than if constructed entirely of iron, and in addition thereto, is not so apt to become electrically charged.

The cylindrical sheet-iron pockets are formed by machinery and in sections of four to six feet long, the ends of which are turned, to receive the supporting brackets, which clamp said pockets end to end. The uprights and brackets are bolted together in a manner as to clamp firmly the ends of the pockets, thus uniting the adjacent sections, and thereby securing a substantially smooth pocket or trough extending from one manhole to the next, the smooth surface overcoming any danger of injuring the cables in the act of drawing them through, and at the same time decreasing the labor. The uprights and pockets with the railway are fitted in the machine shop, and several sections, secured together, are lowered simultaneously to the foundation made for it in the street. These are then closed in and the conduit is complete.

It is estimated that the system just described can be laid with a capacity of 12 to 15 pockets adapted for different companies to occupy separate pockets for their own wires, each pocket having a capacity of 100 to 200 wires (according to the kind of wires or cables are used), for from $8,000 to $10,000 per mile, depending upon the material used in the masonry.

Fig. 6 represents a general view of our electric lighting system in which we have to deal with currents of electricity of high electro-motive force. In such systems in moist weather, or even owing to the dampness of an underground conduit, there is an escape of the current and this materially reduces its tension so as to render the current incapable of producing a light of more than small candle power at a short distance from the generating station. This has been one of the obstacles to placing electric lighting wires under ground where the current was to be conveyed over long distances.

By this system the tension of the current is retained at its maximum, and so far as dampness is concerned the tension is unaffected, thereby conveying currents underground over even longer distances than can be done above ground, under the ordinary variations of the hygrometric state of the atmosphere.

To attain this end the air within the conduit is kept under consider-

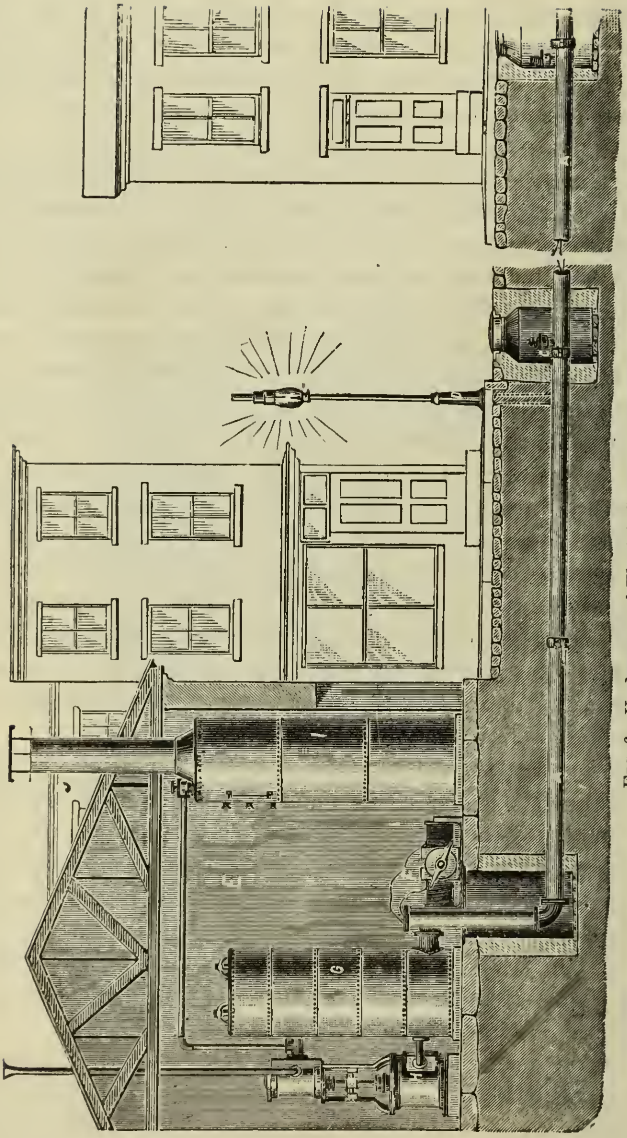


Fig. 6.—Underground Electric Lighting System.

able pressure, and perfectly dry. If there is any appreciable amount of moisture in the atmosphere, the air-pump *H*, forces the air first through a dryer *G*, which absorbs all the moisture, and the chemically dried air passes into the conduit *A*, and when the pressure becomes over a fixed amount, the relief valves *C*, allow the excess of air to pass off, thus keeping the pressure in the conduit uniform. Currents of high tension tend to pass off the conductors, but this tendency decreases as the pressure of the surrounding medium (air) increases, and this effect is greatly increased by the thorough drying of the air in damp weather before passage into the conduit. The drying chemicals may be used over and over again, and the system is adapted to any substantially air-tight conduit. As the pressure is constant there must be an efflux, and should there be a small leak the passage of air will be from inside outward, thus preventing ingress of moist air.

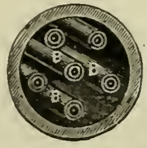


FIG. 7.

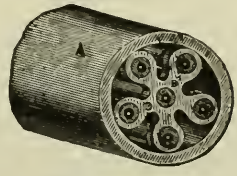


FIG. 8.

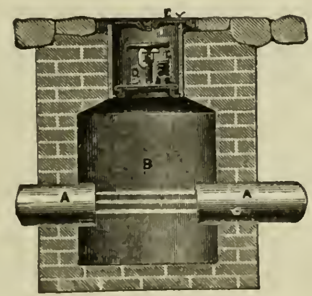


FIG. 9.—Airtight manhole.

Figs. 7 and 8 represent end sections of conduits for electric lighting purposes, in which *B* are the conductors and *A* a metal pipe, the conductors *B* being supported by suitable insulators within said pipe. The conduit *A*, Fig 6, may be continuous with testing doors in the manholes *B*, or if desired the conduit *A*, may be open on the ends where it enters the manhole; as shown in Fig. 9, in which the door *D* is made air-tight and covered by an auxiliary cover *F* on the road, the said door *D* being provided with the relief valve *C*. In this construction the manhole is filled with compressed air.

This principle may be applied to general conduits, which may also carry the electric light wires, or instead of supplying the whole conduit with compressed air the electric light wires may be enclosed in leaden or iron tubes, and when laid in the conduit, air may be forced under pressure through said pipes.

Comments by the Examiners.

While the system just described is more particularly intended for electric light wires, and if applied successfully to currents of high tension, it can more easily maintain a good electrical condition for telegraph and telephone wires; and a pipe conduit $3\frac{1}{2}$ inches in diameter can be laid for about $3,000 per mile, and will contain at least 300 wires.

If absolutely dry air could be maintained in this conduit, no doubt it would be attended with many of the advantages claimed for it. But it would be exceedingly difficult to ensure in any conduit of masonry, however carefully built, absolute immunity from moisture, and to keep such a conduit, with its many manholes and outlets under air pressure, would, it is thought, be quite impracticable.

The employment of an electric motor to run a cord or chain through the duct for the purpose of feeding in the wires appears to be a refinement which, to say the least of it, lacks simplicity. Further, the expense of maintaining dry air under pressure by a separate apparatus would be an expensive process both in first outlay and subsequent maintenance.

The employment of dry air, however, in wrought-iron pipes has obvious merits as a cheap and manageable insulator and is well worthy of being developed. The details of the system have not yet been worked out, and the models exhibited showed a new principle, but not so far a practical system.

THE COSMOPOLITAN UNDERGROUND TELEGRAPH, TELEPHONE AND ELECTRIC LIGHT COMPANY OF NEW JERSEY.

PATENTED MAY 8, 1883.

(*"A. b." of the Section's Classification.*)

This conduit is constructed of highly glazed terra cotta, in sections two feet in length, with a tap joint on the top and ends, and is bedded on a cast iron or terra cotta base plate.

Its interior is fitted with iron frames, placed at suitable distances apart, which clamp large plates of some suitable insulating material, such as glass. If bare wires be used, they may be drawn directly through the holes, but where insulated wires are employed, the openings should be fitted with short sleeves of porcelain or glass, to prevent the insulation being injured.

Some of the sections are fitted with tubular projections for tapping the wires, wherever required, for house-to-house supply.

Cast iron manholes are placed at suitable intervals.

The slack of the wires is taken up every fifteen feet, and the wires are then clamped.

All the joints are carefully cemented in order to exclude moisture.

It is stated that about one hundred yards of this system has been under trial in Fourth street, Camden, N. J., and that the cost will not exceed one dollar per foot run.

No provision is made for overcoming the effects of induction in telephone wires. After the duct has been laid and filled with wires, no addition or alteration to the wires can be made without laying open the street down to the level of the base of the conduit and remaking all the joints.

THE ELECTRIC TUBE COMPANY.

UNDERGROUND CONDUCTORS.

Statement of the Company, edited by the Examiners undersigned.

The essential form of the conductors exhibited by this company is that of an iron tube containing one or more copper conductors insulated from each other and the enclosing iron tube, and having all remaining spaces in the latter filled with an extremely viscous, almost solid, insulating compound, which becomes fluid at a high temperature. This manufactured product is termed an "Electric Tube." These tubes are manufactured in fixed lengths, generally twenty feet. The conductors project from two inches to three inches beyond the end of the enclosing iron tube, and two lengths of electric tube are joined together by means of copper joints soldered to the projecting conductors and so formed as to allow the expansion of the conductors to take place without injury or danger. Such joints are protected by a cast iron box completely enclosing them and securely fastened to the ends of the tubes enclosing the conductors. This box is then filled with the same compound as the tube and hermetically sealed.

The exhibit of this company showed the great range in the size and number of conductors which the fundamental form of cased conductor permits, and the great flexibility in making circuits of complicated ramifications, which is given by the plan of having joints at frequent intervals; and the methods of making these joints.

To illustrate the range in size, etc., samples of electric tubes were shown containing conductors varying in number and size, from a single round conductor 1·61 inch diameter, of 2,592,100 circular mils. or 2·036 square inches sectional area, in an iron tube $2\frac{7}{8}$ inches outside diameter, to 271 wires No. 14 Brown & Sharpe gauge, of 4,100 circular mils. or ·00322 square inch sectional area, in an iron pipe $3\frac{1}{4}$ inches outside diameter.

To show the manner in which circuits of a complicated character may be made with this form of conductor, circuits such as those used for incandescent lighting on a large scale, having a large number of derived circuits with conductors of widely differing sizes, there was exhibited a portion of an underground circuit such as is used in T. A. Edison's 3-conductor system of incandescent lighting—a system using tubes of which the cross section is shown by Fig. 1.

This exhibit consisted of, first: a "Junction Safety Catch Box." This is a large round box the top of which is flush with the surface of the street; it is provided with a loose outside cover, and a lighter inside cover bolted down to make a water-tight joint with the box; these being removed, disclose the internal electrical connections in a readily accessible position, six inches below the surface of the street. The central portion of the box is occupied by the "Pole Pieces," consisting of as many rings as there are conductors in the system (in this instance three), each ring having as many radial projections as there are tubes entering the box (in this instance six), these projections, which are symmetrically arranged as regards polarity, are all brought to the same level at their extremities and terminate in plane, polished, gold-plated surfaces one inch square, which are arranged equidistant from each other in a circle around the centre of the box. Each of these surfaces has a tapped hole in the centre.

Fig. 1.

In a circle outside the pole pieces, are as many "Safety Catch Joints" as there are conductors entering the box (in this instance 18), these safety catch joints are arranged radially opposite the extremities of the projection of the pole pieces; each consists of a copper or composition piece which has a copper rod soldered into it projecting about eight inches downwards into the body of the box, the upper end of the composition or copper piece terminating in a plane, inch-square, gold-plated surface, the same as those on the pole pieces. These surfaces of the safety catch joints are on the same level as the similar surfaces on the pole pieces, and radially opposite and equidistant from them.

Two feet below the top of the box (that is the surface of the ground) the electric tubes (in this instance 7) enter the box and are rigidly attached to it, the joint being made water-tight. The pole pieces and the safety catch joints are all insulated from each other, but rigidly attached to a support rising in the centre from the bottom of the box.

Flexible copper cables join each conductor, of each tube, with one of the copper rods which project downwards from the safety catch joints, so that by means of flat safety catches placed across from the safety catch joints to the corresponding projections of the pole pieces, all conductors of like polarity are joined together at this point with a safety catch in each circuit in a readily accessible position, where it can easily be removed or replaced. Such a box equalizes the electromotive force at that point of all lines entering it, or if one of the tubes is a feeder, that is, runs back to the dynamos, the box is a distributing point for several circuits which may or may not be brought together again at some other place.

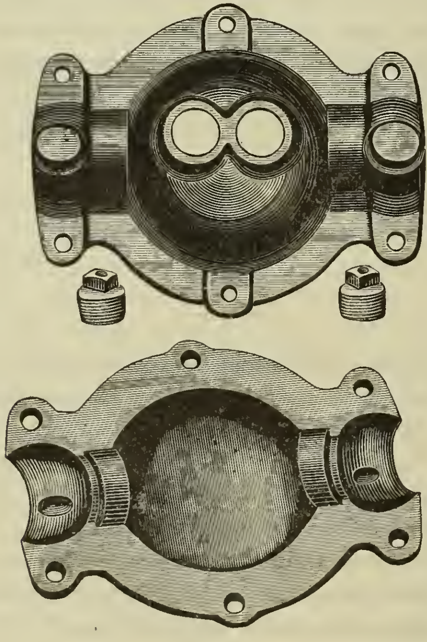


Fig. 2.

The conductors in the tubes entering this box may be of any size to suit the requirements of the different circuits. The circuits shown entering this box vary from 350,000 circular mils. to 133,000 circular mils. area of conductor, and are arranged to show how they may be laid, bent in different degrees to right or left, joining each other at their extremities; crossing each other and joined together at the crossing; joining other circuits at any point in the length of the latter;

reduced in size at any point of their own lengths, and having derived circuits of any size taken from them at any point of their own lengths; and having all these varied connections of different sized conductors made by means of a comparatively small number of standard patterns of connecting joints, boxes covering the joints, and ball clamps attaching the boxes to the iron tube enclosing the conductors.

The ball clamps, in connection with the boxes, are essential features of all underground conductors of this company's exhibit.

Figs. 2, 3 and 4 illustrate the forms of these parts and the manner in which they are used.

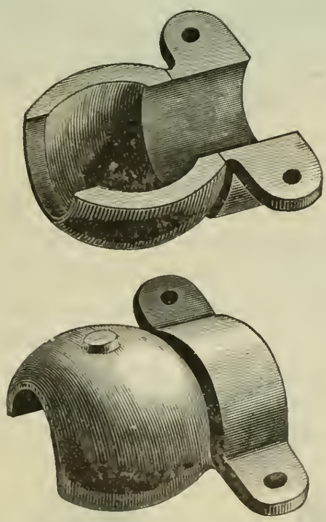


FIG. 3.

Fig. 2 shows the top and bottom halves of a "Coupling Box," a 3-conductor system, and Fig. 3 a "Ball Clamp," whilst Fig. 4 shows the bottom half of the same coupling box with tubes and ball clamps in place and joints connected. The two parts of the ball clamp being bolted together on the tube are thus securely clamped to it, the hemispherical parts come together to make a sphere which fits the spherical socket in the nozzle of the box; the two together thus form a ball and socket joint, allowing free angular movement of the tube in any direction, but preventing longitudinal movement of the box on the tube. The angular movement allowed by the ball and socket is limited to any amount in any direction, by providing a rib inside the box (either separate as in Fig. 11, or forming the inside opening of the ball-socket of the box, as in Fig. 2) of such a form, that when the extreme amount of angular movement to be allowed in any one direction is obtained, the tube projecting into the box through the ball clamp comes in contact with this rib, thus stopping any further movement in this direction.

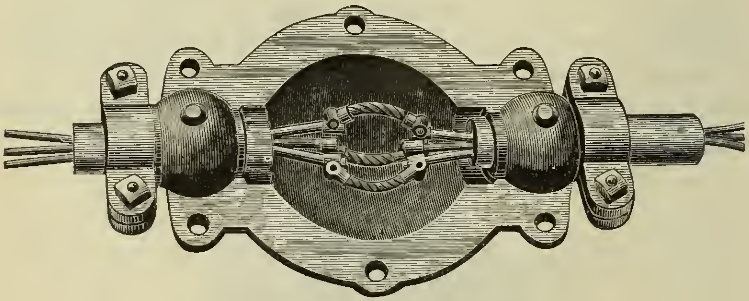


Fig. 4.

The box is made of such size and form, that when the tubes have the extreme angular movement allowed there is still ample space between the joint and the box to prevent the two coming in contact. Rotary movement of the box on the tube is prevented by means of the small lug on the ball of the clamp which loosely fits sidewise, the slot shown in the socket of the box, the slot being sufficiently elongated lengthwise that the lug may have free play in that direction within the limit of angular deivation allowed.

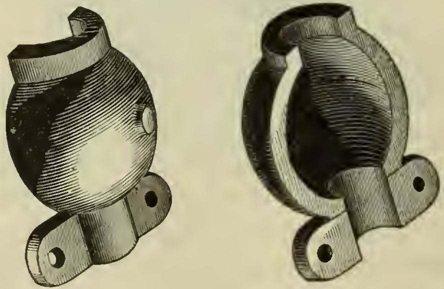


Fig. 5.

The limiting rib inside the box is made to give the angular movement allowed, when the largest size of iron tube that will go into the box is used, but any smaller iron tube may be used in this box (as, for example, in reducing the size of the conductor at this point) by means of a ball clamp, of the form shown in Fig. 5, with a ball to fit the box, but with a smaller semi-cylindrical groove in each half to fit the smaller iron tube; this clamp has in addition, as shown, a semi-cylindrical ring concentric with the groove cast on the ball of each half; the two, when the two halves are clamped together on the iron pipe, forming a cylinder projecting into the box, of the same outside diameter as the largest iron tube that will go in the box: this projection on the clamp striking against the limiting rib inside the box, limits the angular movement of the smaller iron tube to the same amount as when the largest size of iron tube that will go in the box is used. Therefore the ball clamp and box, as described, whilst making the iron envelope of the conductors mechanically continuous, and preventing rotary movement of the boxes on the tube; allow an angular deviation (in this case 1 in 10) in every direction, at each end of every box, which gives a degree of flexibility to the whole line (in this instance 11½ degrees at each joint) and at the same time renders it impossible that the joint should touch the box, with the extreme amount of angular deviation allowed. The ball clamp, modified as shown in Fig. 5, also permits the use in any box of any tube smaller than the largest that will go in the box, whilst preserving the same limit of angular movement.

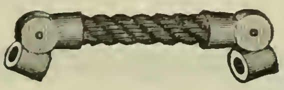


FIG. 6.

The flexibility of the whole line thus obtained is necessary for rapid and cheap laying in streets, where, from the number of gas, water and other pipes, sewer-manholes, etc., it is impossible to run tubes in a straight line for any distance.

The joints for 3-conductor tubes consist of pieces of copper wire rope, having cast or brazed on their ends suitably shaped composition sockets, in which are drilled holes to fit the size of copper conductor for which they are intended, and to which they are soldered in laying the line. The joints necessary to obtain the results illustrated by the exhibit are: "Coupling Joints," for connecting two tubes in a straight line (Fig. 6 shows the form of one piece, three such pieces being used for a complete joint); "90° Elbow Joints," for bending 90° to right or left, and "45° Elbow Joints," for bending 45° to right or left. Fig. 7 shows three forms of pieces, different combinations of which will make all kinds of elbow joints. "Branch Joints," by which, to any coupling joint in a line of any sized electric tube, may be attached a branch to one side, or one to each side, of any sizes not larger than the main line. Branches of sizes larger than the main line, being of rare occurrence, are not allowed for in the standard patterns for branches enumerated below, but, when required, may be made by a slight modification of the latter. Fig. 8 shows three forms of pieces, different combinations of which will make, to either or both sides of any coupling joint, branches of all sizes ordinarily required; a few of the largest sized branches require special patterns of modified forms, which are enumerated below. The form of socket of the coupling joint shown in Fig. 6 gives the copper wire rope of the joint a bowed form when the joint is in place, to allow for the expansion of the conductors in each electric tube. The form of the joint when in place is seen in

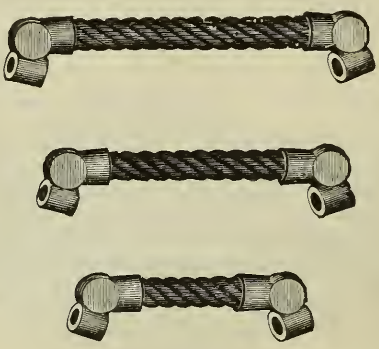


Fig. 7.

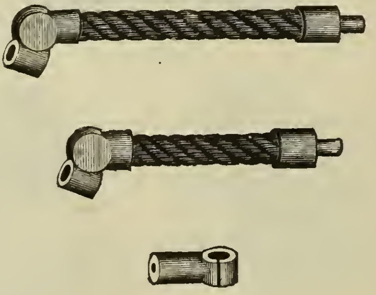


Fig. 8.

Fig. 2. Fig. 6 shows that, in addition to the hole which fits the conductor, each coupling joint socket has another hole drilled in it; the male sockets on the ends of the branch joint pieces (see Fig. 8) fit these holes and are soldered in them in attaching a branch joint; the female sockets on the other ends of the branch joint pieces are drilled to fit the conductors of the electric tube used for the branch lines. Fig. 9 shows a coupling joint, with a branch joint attached, in the bottom half of the box used for covering this kind of joint.

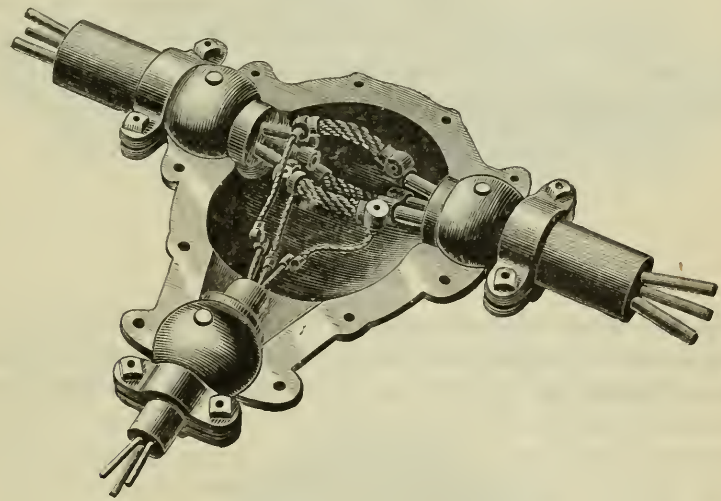


Fig. 9.

The 3-conductor system, so far as it is exhibited, has 21 different sizes of electric tubes, having conductors varying from 500,000 to 27,000 circular miles sectional area. The enclosing iron tubes are of 5 different sizes, varying from $2\frac{3}{8}$ inches to $1\frac{1}{16}$ inches outside diameter. All connections are made with 10 patterns of boxes, 8 patterns of ball clamps, and patterns of 43 pieces for all joints; of the latter, 6 patterns are required for coupling joints for all sizes, 3 of these patterns are also used for elbow joints, which require 15 patterns in addition, making 21 patterns for all varieties of all sizes of coupling and elbow joints. The remaining 22 patterns are for branch joints, and 12 of these will make any combination ordinarily required, the other 10 being for use in cases which rarely occur.

Electric tubes are exhibited cut away to show the internal construction, which consists in wrapping each copper conductor with a layer of insulating tape, and winding each taped conductor spirally with rope impregnated with insulation; the pitch of this winding is large compared with the diameters of the rope used, so that the windings of the several conductors fit between each other when the conductors are placed together; as many conductors as are to go in one tube, being so placed together, they are bound together by a final spiral winding of rope around them all, and the bundle of conductors thus formed being introduced into an iron tube, the process of manufacture is completed by filling the tube with insulating compound liquid, at high temperature, ready access being afforded the latter throughout the length of the tube, along the spiral paths formed by the rope-winding of the conductors.

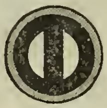


FIG. 10.

Another variety of electric tube is illustrated by an exhibit of a complete set of sample tubes for the 2-conductor system of incandescent lighting, and typical examples of the boxes, ball clamps and joints used with them. The conductors in this system vary from 1,639,890 circular mills, or 1·2879 square inches, sectional area in a tube $3\frac{1}{2}$ inches outside diameter, to 33,015 circular mills, or 0·02593 square inches sectional area in a tube $1\frac{1}{16}$ inches outside diameter, and, there being only two in a tube, economy of space in the latter is secured by making the conductors in the form of segments of circles, as seen in Fig. 10, which shows a cross section of one of these tubes. The joints for these tubes are of cast copper, the allowance at coupling joints for expansion of the conductors being given by making the joints with a U-shaped bend, projecting at right angles to the line of the tube, the section of the joint in the U being flattened to a parallelogram, long in comparison with its width, as is seen in Fig. 11, which shows a coupling joint for this system of tubes, with bottom half of coupling box. Holes are bored in all joints of the same form as the conductors for which they are intended, and to which they are soldered in laying. Boxes are exhibited with short tubes entering them, and joints connecting the latter, showing the forms assumed by different sizes and varieties of coupling elbow and branch, joints and boxes. Fig. 12 shows one variety of one size of 90° elbow joint, with bottom half of elbow box.

In both the 3 and 2 conductor systems, boxes and joints are shown for use in in-door lines of these tubes. The flexibility of the line which is required for underground work, and which is given by the ball and socket connection of clamps and boxes, is not necessary in in-door lines; the boxes may therefore be smaller on this account, and also on account of the absence of the ball clamps, the mechanical continuity of the iron envelop of the conductors being secured in small space by means of a ring which is screwed on the threaded end of the iron pipe and fits in a groove cast in the neck of the box (which neck fits the iron tube); this box is made in halves, which are bolted together over the joint, the end of the tube, and the ring screwed on the latter.

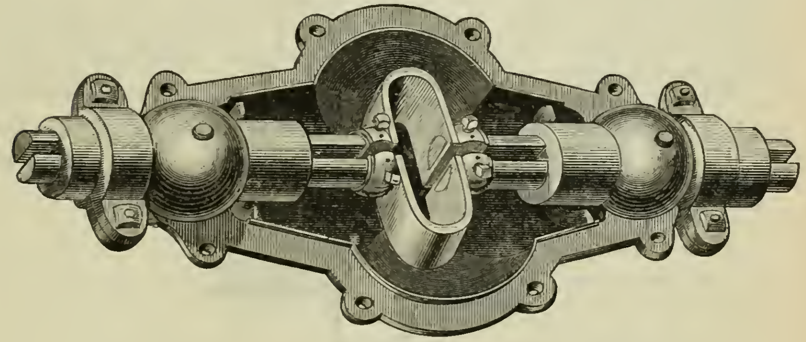


Fig. 11.

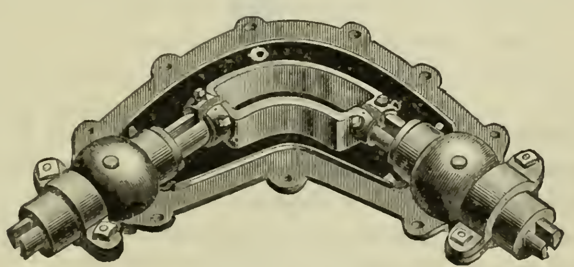


Fig. 12.

Underground arc light circuits were illustrated by two exhibits showing the character of the tubes and joints and the method of taking loops to lamps. One showed tubes with two round conductors for a complete circuit in one tube.

Fig. 13 shows this exhibit, and the method of making the joint so that, the branch tube being led off to a lamp or lamps, the two conductors of the branch form a loop of the main line. The second exhibit shows the case of a circuit completed by a line on another street. In this exhibit the main line tubes entering the box have only one conductor each, the conductor of each tube being joined to one of two conductors of the third tube, forming a loop from the main line of a single conductor. The joints are of wire rope of the same character as the joints for the 3-conductor system. Ball clamps are used to connect tubes with boxes.

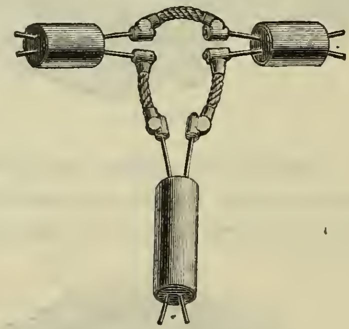


FIG. 13.

A distinct variety of electric tube is that designed for telegraphic and telephonic use. In this case, the conductors being large in number and small in size, instead of the spiral rope winding round each conductor, the insulating covering is continuous, and a rope winding is only used round the outside of a bundle of such wires. The wires are laid together regularly, on the basis of a hexagonal cross section for the bundle, and at each end are threaded through wooden screens which have holes drilled in them, in the same relative positions as the wires occupy in the tube. At one end of each tube, before being threaded through the screens, the wires are woven together so as to change the relative positions of the wires. This operation of weaving is simple and systematic, and the same for all tubes with the same number of wires, and is arranged on such a basis, that in conjunction with a systematic rotation of consecutive tubes, alternately to right and left, in the process of laying, it produces, in a series of long period, methodical changes in the relative positions of the wires in consecutive tubes, for the purpose of neutralizing the effects of induction. In making the joints of these tubes, wires threaded through corresponding holes in the screens are bent outwards and placed together in the same notch of a series of notched wooden slats, one for each layer of wires in the joint, which are built up one above the other, as the process of making the joint proceeds. When all the wires are so bent out, the ends are clipped off, leaving about 1 inch projecting through the wall of notched slats; the insulation is then slipped off the ends and each pair joined by a small sleeve, which is soldered to them to make the joint. In general, the joints of half the wires are made on one side and half on the other side of the box. Grooves are provided in the boxes into which they fit the wooden screens through which the wires are threaded, and the series of wooden slats built up in making the joint, holding these securely in place. By this method of making the joints, every joint of every wire, at intervals of 20 feet, is brought into a position in which it is readily accessible for purposes of testing, making connections, etc., without interfering with any other wire, so that at any such joint, loops or single service wires may be attached to any or all of the wires in the line. A line of this character, containing 37 wires was exhibited, with several consecutive boxes and joints to show the system of weaving wires in conjunction with alternate rotation of tubes. Such a line is adapted more particularly to telegraphic uses. Another box was exhibited, constructed with especial reference to the needs of telephone service, for which, in addition to trunk lines between stations, a number of wires are required for services in each block, and only run from the station to that block, thus giving a line between two stations a size decreasing gradually from each station to some point between them. The box exhibited, which showed a joint in a line of 217 wires, had a low turret rising from its upper half, the top of this turret was closed by a loose outside cover and an inside cover bolted down, and making a tight joint with the box by means of a rubber gasket; the whole being made water-tight by filling the space between the two covers, with the insulating compound. In every such box, along the face of a block, all those wires which are intended for use as services in that block, are bent upwards instead of outwards, in making the joint so that the joints of all such wires project upwards into the turret and are held in position by a wooden frame shown, whilst the the joints of all other wires are made out to the sides at a lower level;

this arrangement allows the box to be filled with insulating compound, covering all the wires and all joints, except the joints of those wires intended for use in that block, which latter joints project up above the surface of the compound, and on removing the cover of the turret are all immediately acccessible at every box along the block, for attachment of services, to any or all of them. Tapped holes are provided around the turret on the level of the joints of service wires, into which service tubes may be screwed, if electric tubes are used, or brass nipples to which are soldered the lead covering, if lead covered wires are used for service connections.

This company also exhibits specimens of lead covered wires of small sizes, and a specimen of flexible heavy conductor for indoor use, with large currents consisting of copper wire rope, taped, wound and lead covered. They also exhibit specimens of insulating tape, in rolls of 125 feet, continuous length, varying in width from 6 inches to ¼ inch, and jars of the insulating compound used in the tubes and boxes.

Comments by the Examiners Undersigned.

This system may be summed up as belonging to division "A a" of the Section's arrangement, or that in which the electrodes are permanently sealed. When any portion of an electrode is destroyed a new one is not introduced, but a new length of pipe is substituted, containing the necessary number of wires and attached at its extremities. The details are very fully given, and with the cuts render it unnecessary to repeat them. With a large stock of lengths and boxes and with trained workmen, the work of laying the conductors only a few inchee below the surface of the streets would be comparatively rapid. While in the tentative stage of underground service this does not present the same amount of convenience as a system where wires may be introduced and removed at will; and presents the objection common to all "section" systems that the conducting capacity of the whole line is that of the most imperfect of splices made every twenty feet, yet it answers the demands upon it much better than those systems which require expensive and tedious derangements of the street in order to accomplish repairs. The seat of an accident to one of the wires of this system is located from the central office, on and between known streets. The manhole is opened and the safety catches first of all examined. The managers assert that the place of the break can then be so accurately located that the length containing it (usually about twenty feet) may be at once removed and replaced by another.

The telephone and telegraph, and the light and power wires are not enclosed in the same tube. The insulating material with which the boxes are filled is still flexible at 32° F., but brittle at 0° F.

The method of laying and tapping for private dwellings would seem to afford complete protection against lightning. The three-wire system which has been grafted upon the Edison conduit system effects a saving of 62 per cent. on that required for the two conductor system, in the copper necessary for conductors.

The light and power system are not adapted for use by various companies, independently, though the telephone and telegraph conduits might be so applied.

The details of this system have been so perfectly elaborated, that in view of the fact that no complete description of it has been heretofore made public, the undersigned deemed the above full report desirable.

THE NATIONAL UNDERGROUND ELECTRIC COMPANY OF NEW JERSEY.

("C." of the Section's Classification.)

This conduit consists of a number of metal tubes imbedded in a kind of insulating pitch, formed in a suitable trough. At the corner of each street there is a water-tight man-hole for hauling in or out wires as required. Provision is also made for tapping wires for house-to-house supply. This forms the subject of a separate patent. It is proposed to place telephone, telegraph and electric light wires in different tubes, so that they shall not interfere with one another. The metallic lining of the ducts, it is claimed, will pass off readily any induced currents which may be generated. The moisture or damp can be kept out by forcing dry air through one or more of the tubes or conduits from a fixed plane along the line.

The Company state that the cost of the conduit per mile will be $8,300. A mile of conduit has been laid under Market street, Philadelphia. The committee were unable to examine its condition, as it contains no wires at present.

(No electrotypes were furnished by the company to accompany this report.)

HENDLEY'S CONDUIT FOR UNDERGROUND LINES.

"A. b." of the Section's Classification.)

Description of Inventor, edited by the Examiners undersigned.

This system consists of a semi-cylindrical trough or conduit for the reception of the conductors, with a suitable cover of any desired configuration, angular shaped being preferred, as by its removal, when necessary, the wires and their supports are more thoroughly exposed. Below the trough and integral therewith, is a drain-pipe of suitable diameter, for carrying off all moisture that may find its way into the conduit by condensation, exudation or leakage. A narrow slot extending throughout the length of the trough opens therefrom into the drain-pipe, the curved sides of the former rendering it almost impossible for any heavy particles of moisture to remain therein, this slot serves also to sustain the bolts which pass through the shoe to which the standard of the wire supports are secured, thus rendering it easy to place the supports at such intervals as may be desired, along the conduit. This structure, with the supporting arms is really "a telegraph pole underground." Modifications of these slotted arms have been suggested, which it is thought would, in practice, make this feature thoroughly effective.

Testing chambers are placed at such suitable points along the line as may be necessary, and in these, provision is made to test, tighten and otherwise manipulate the wires. A full description of this feature of the system cannot be fully set forth herein. At one side of the conduit brackets are secured, and from these rods extend, over which travelers having suitable pulleys in their interior which move on the rods, pass and carry the wires from man-hole to man-hole, cords are attached to each side of a traveler, and pass thence to reels secured near the surface of the earth, these man-holes can be placed at frequent intervals along the line, by securing wires to a suitable clamp at the bottom of the traveler, and they may be run in at any point simply by reeling in the cord.

Pipes for inducing currents of air are led into chimney stacks the heat of which is made available for that purpose, or they may pass into the open upper air, and currents of hot or cold dry air may be forced into the conduit by means of fan blowers, both devices may be used, though either separately would be effective for carrying off all

Fig. 8.

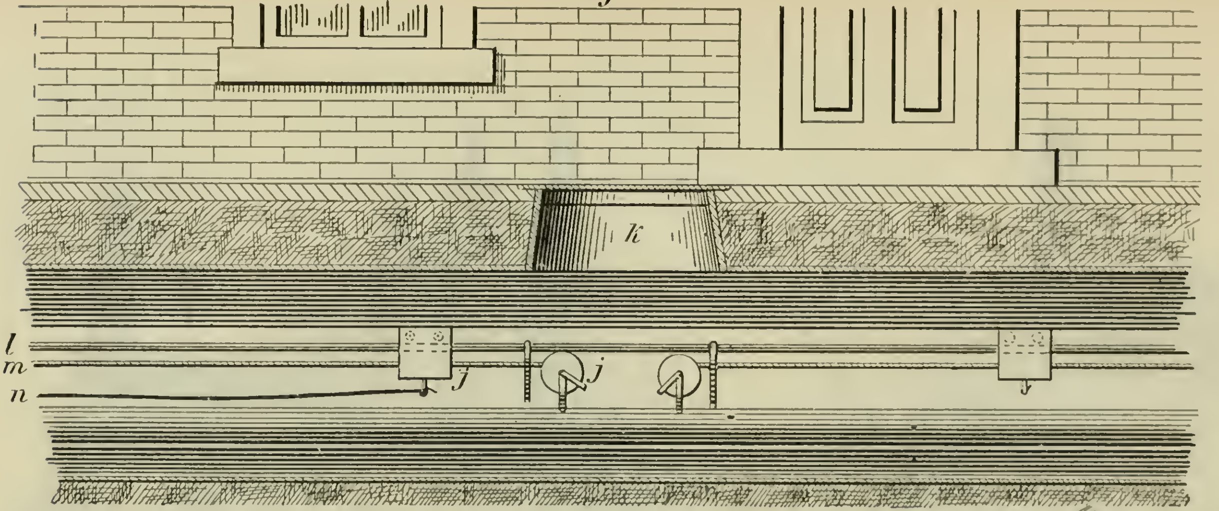


Fig. 9.

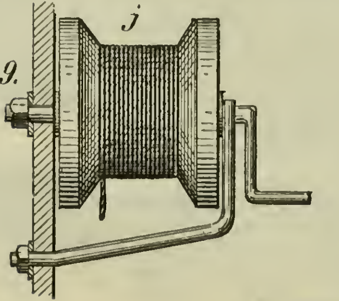
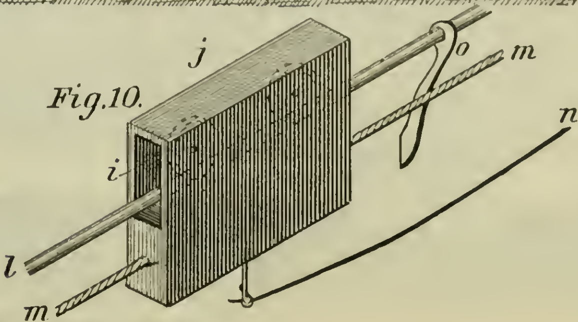
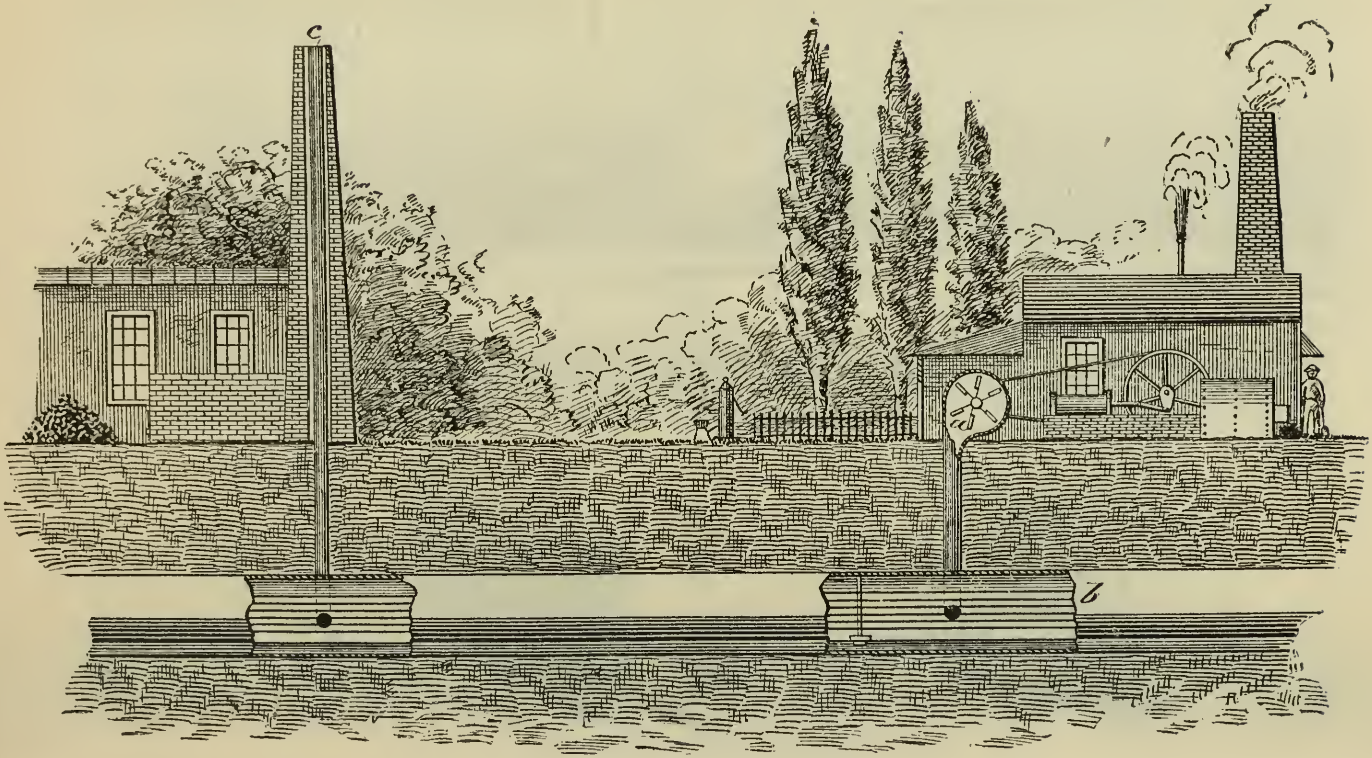


Fig. 10.



Hendley's Underground Conduit System.



Hendley's Underground Conduit System.

the lighter particles of moisture, and thereby keeping the conduit thoroughly dry and at a uniform temperature all the year round, and thus rendering, it is thought, a thorough insulation of the conductors unnecessary. Provision may be made by this system for a future increase in the number of conductors to be employed, without having to tear up the streets, so that when once the system is built it remains a permanent and available plant, adapted not only to present but to future use.

Comments by Examiners.

This conduit consists of a semi-cylindrical trough of iron, terra cotta, or preferably, of glass, fitted with an angular-shaped cover. At the bottom of the conduit there is a pipe connected to it by a slot, for the purposes of drainage, and for fixing a standard with recessed and insulated arms for carrying the wires.

Man-holes are provided at suitable points, and also small pipes for house to house supply.

Provision is made for either ventilating the conduit by induced currents of air, or of forcing hot or cold air through it in order to expel all moisture. No provision is made for induction in telephone wires. The standards carrying the wires are secured to the conduit by one bolt each, and it would seem difficult, without continual inspection, to keep them in position.

NOTE.—Neither the inventor nor any one representing him could be found to answer the questions of members of the Section as to his method of running in wires, etc., and no estimate of cost was furnished.

MAGNER'S UNDERGROUND CONDUIT.

PATENTED JUNE 10, 1884.

("A. b." of the Section's Classification.)

This system consists of a conduit constructed of cast iron, terra cotta, etc., having a longitudinal slot A' at its top, for the introduction of wires or cables. This slot is beveled and made tight by bolts and clamps bearing on the inside of the conduit (See Fig. 5.) The joint is further secured by suitable packing.

The wires or cables are supported on insulated rollers, which revolve freely on a series of horizontal shafts, suitably supported and arranged one over the other. These rollers may be formed in one piece, or may consist of a number of independent rollers separated by washers. The distance apart of the rollers both horizontally and vertically, is such as to prevent contact between the wires or cables, when strained up.

The Inventor claims that his system provides a conduit applicable to all descriptions of wire or cable; which is easy of access for the insertion or removal of any wire or cable, and in which the wires are kept taut.

The Inventor did not submit any plan for manholes, or any arrangement for providing house-to-house supply, nor does he claim any method of obviating the efforts of induction. He proposes to lay down well insulated wires, as the conduit would be necessarily more or less damp.

After the conduit has been laid and filled with wire, any alteration to the system would require that the street should be opened from end to end.

FIG. 2.

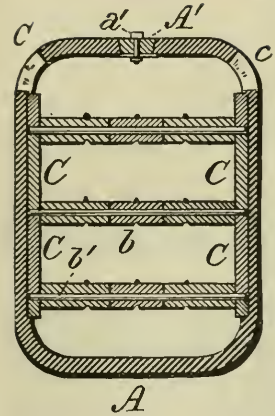


FIG. 1.

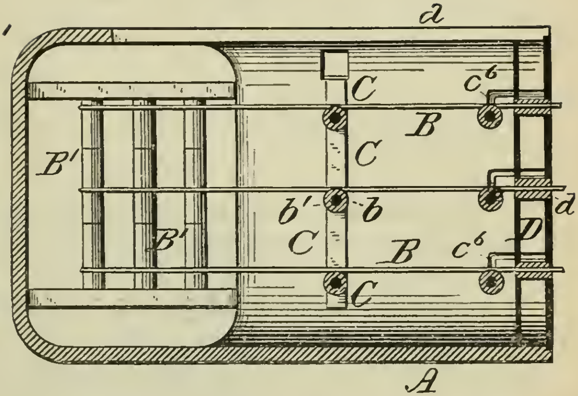


FIG. 5.

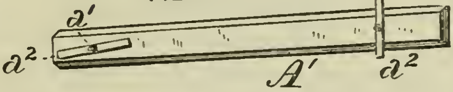


FIG. 6.

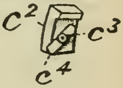


FIG. 4.

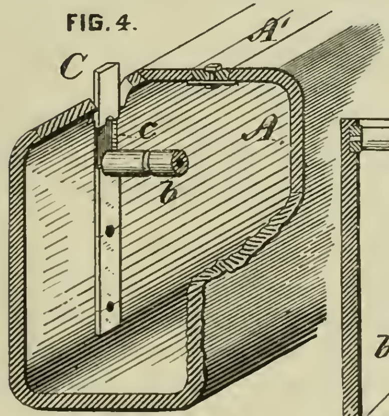


FIG. 3.

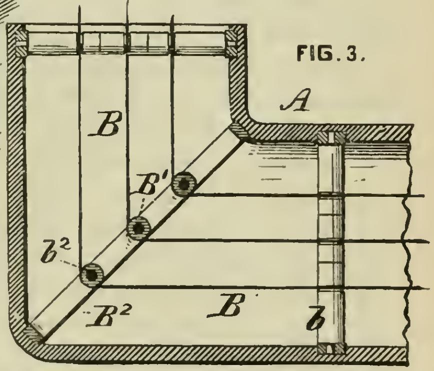
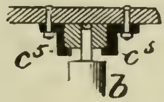


FIG. 7.



PHILADELPHIA AND SEABOARD TELEGRAPH AND CABLE COMPANY.

(CALLED ALSO PENNOCK'S.)

(" A. a." of the Section's Classification.)

Description of Pennock's Underground Conduit for Telegraph and Telephone Wires.

The material used in constructing this conduit, consists of hemlock wood, copper wire, various compounds and insulations, the nature of which the inventor did not disclose.

The wood is exposed to a solution for several hours, at the temperature of boiling water. The composition being easily distributed through the mass of soft wood, incrusts the cells with a compound which makes the wood absolutely moisture and decay proof. The carpenters now take the wood (which has become dry and hard) and make a hollow box—the core of the conduit—which is filled in with insulated telephone wires, arranged according to a plan not disclosed. When the core is filled, insulating material is again poured upon the wires, filling in the interstices, making a dry solid mass. The top is now cemented on. The finished core now receives a second coating of the waterproof compound. (Fig. 1 shows the completed core.) Around this core are now built the receptacles for the insulated telegraph conductors (as shown in Fig. 2.) There are two inches of insulating impermeable compound between the telephone and telegraph circuits, 6 inches between all sides, $\frac{1}{2}$ inch all around.

The finished core is now set in the outer shell of the conduit, which is also made of the prepared wood, 1 inch thick. A moistening compound is now run in around the core and the top covered with a plank of the same prepared wood, pressing into the compound, making two inches of solid impermeable matter between the core and the casing, three inches between the core and the earth, 5 inches between the telephone and the earth. The sections are all prepared at the factory before being taken on the ground. They are run into sleeves every 20 feet; 20 loops are run out on each side of the sleeve and covered with a water-proof cap, so that the wires are at all times accessible. The wires are connected through the sleeve with a patent, hard paper, double connector.

The electric light conduit is made in a similar manner, but the wires

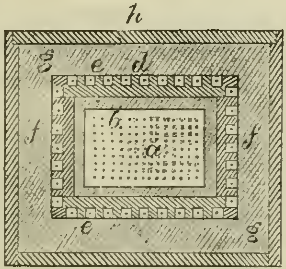


Fig. 1

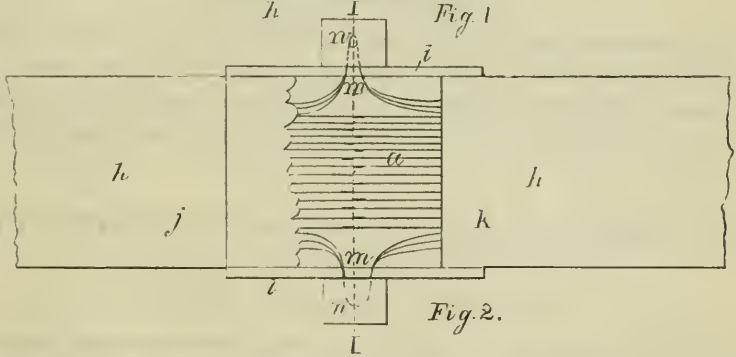


Fig. 2.

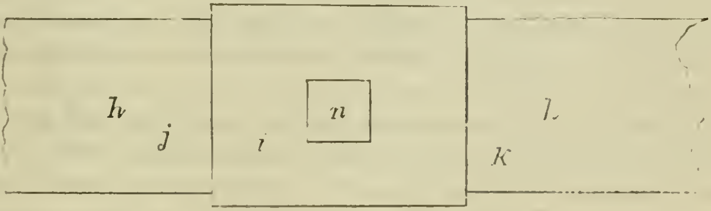


Fig 3.

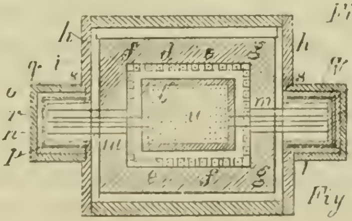


Fig 4

Pennock's Underground Conduit System.

are widely separated, and different materials are used in insulating and fire water-proofing.

The advantages claimed for this system are: (1.) It is fire-proof; (2.) It is water-proof, it will not decay; (3.) It is a perfect insulator; (4.) No leakage between telephone and telegraph wires; (5.) The arrangement of the conductors in the lanes to divert induction, etc.; (6.) The wires will not corrode; (7.) The wires cannot break, no pulling of cables through tubes, no abrading, no strain; (8.) Insulated wires can be tapped and conveyed into each dwelling without disturbing the main conduit; (9.) It is cheaper than a pole line.

Price per mile for 100 Telephone wires, delivered on ground........	$2,500
Price per mile for 1000 Telephone wires, delivered on ground........	$9,750
Price per mile for 100 Telegraph wires, delivered on ground........	$2,750
Price per mile for 1000 Telegraph wires, delivered on ground........	$12,750

Comments by the Examiners.

The whole success of this sytem would depend on the nature of the insulating material and the chemical preparation of the wood, etc. Without trial, over an extended period of time, it would not be possible to test this conduit for endurance and the other points claimed by the inventor.

THE UNION ELECTRIC UNDERGROUND COMPANY OF CHICAGO.

(*"A. a." of the Section's Classification.*)

This conduit consists of a tube ten inches in diameter, of kalamine (a mixture of lead and tin) which is said to resist the chemical action to which all underground conduits are subjected—on each side of this main, smaller tubes of the same metal, two inches in diameter. The large tube is designed to accommodate the main wires and the small tubes those which run short distances, and at regular intervals there are joints by which house-to-house connection can be made. Instead of the wires being covered with an insulating coat, from which they cannot be withdrawn, they run through a tiny pipe, a little smaller than the familiar maccaroni tube, and this pipe is manufactured independently of the copper wire. When this pipe has been tested, the copper wire is forced into it by an ingenious machine. Should the copper wire at any time need repairing the same machine withdraws it from the well-fitting covering and then replaces it.

The inventor claims that this tiny tube is the best insulator known. It is made of vulcanized rubber, three sixteenths of an inch being its thickness, and one-sixteenth of an inch being the diameter of the opening. The rubber is covered with a thick electric deposition of copper. The deposition surrounds the tube and is said to prevent induction by carrying the surplus electricity into the ground.

By the tube system each wire can be removed without the others, with which it is bunched, being disturbed in any way. The electric light wire which, on account of the great insulation, can be handled with perfect safety when the strongest current of electricity is running on it, costs less than $500 a mile, or half the usual cost, and takes up about half the space that an electric light wire usually occupies.

The inventor claims that by the use of his special insulation he can run all descriptions of wire in one tube.

The conduit can be laid for $8,000 a mile. The main tube will hold 1,700 wires, and the side tubes 50 each.

The insulation was found to be very brittle—and it would be difficult to bend it out of the manholes and tapping tubes without injury. The wires must be necessarily very expensive—not only to manufacture, but to force into their insulated tubes afterwards.

WOODWARD'S CURB CONDUIT.—SYSTEM B.

(*" A. b." of the Section's Classification.*)

Company's Description Edited by the Undersigned Examiners.

In the accompanying engraving, Fig. 1, is a perspective view of the combined curbstone and conduit, showing the wires in position; in the second figure the wires and cover are removed; Fig. 3 is a vertical section taken at a street corner; and Figs. 5 and 6 are plan views at street corners, the former being an inlet corner and the latter the usual rounded corner; Fig. 4 is a horizontal section illustrating the method of securing together the conduit sections in order to permit expansion and contraction. The hollow curb conduit sections, *A*, made of cast iron or other suitable material, are formed with vertical sides above the street pavement to form the curb, and those portions sunk in the ground are widened out at the bottom to guard against displacement and provide ample space. The cover, *J*, is about flush with the sidewalk. Between the cover and the top of the ledges is placed a water-tight packing. The wires are supported by a series of vertical racks, *E*, fixed at suitable intervals apart. The lower ends of the racks enter sockets in the bottom of the conduit, while their upper ends pass through holes in cross stays, *D*, the extremities of which rest in brackets on the sides. The ends of the conduit section are flanged and bolted together, packing being inserted between them.

When it is necessary to provide for longitudinal expansion and contraction of the several sections, they are made with overlapping ends, and are secured by bolts passing through slots in one of the flanges. Packing is placed between the joints. The wires are inserted from the open top of the conduit and rest in the teeth of the racks; after they are in position the cover is bolted down. When it is desired to conduct one or more wires into a building, small lateral pipes, *L*, are connected to the side of the conduit. With this construction the wires are always easily accessible and the tearing up of the pavement in order to reach particular points is obviated. The two-plan views show clearly the methods of rounding corners. When the conduit crosses the street where the curb ends, those wires which are above the line of the depressed part are directed downward (Fig. 3), and kept in place by means of transverse studs, *N*.

The advantages claimed for this system are: That it is easier and cheaper to place the wires in the curb than to tear up the streets and put them in an underground conduit.

That owing to the curb conduit widening and deeping from the level of the paved street it gives ample room for holding any number of wires.

That to introduce into a house any telegraph, telephone or electric light wires, by merely removing a few bricks from his pavement, the connection is made direct with the curb conduit, instead of excavating many feet of earth in the pavement and the street by the underground conduit.

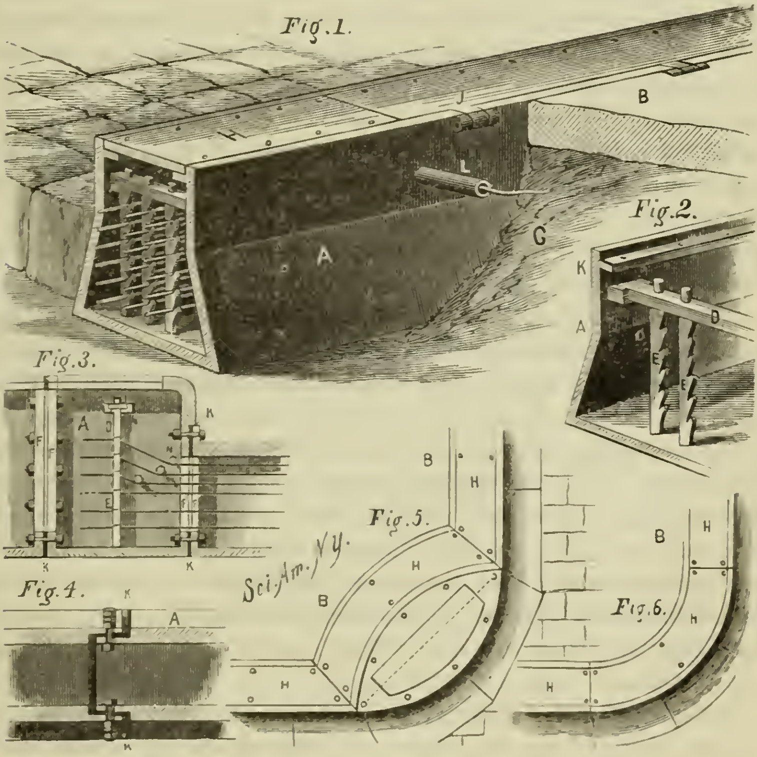
That it is always accessible.

If anything happens to a wire, or a new one is to be introduced, one can always get to it in the curb conduit, and during the snow and ice of winter when the authorities of cities will not allow the streets to be opened, the curb conduit is as accessible as in the warm months of summer.

Comments by the Examiners.

In this system no provision is made for keeping the conduit free from moisture, so that a first-class insulation is required for the wires or cables used. Further, no method is proposed for obviating the efforts of induction in telephone circuits.

To obtain the advantages claimed for it, a conduit must be run on both sides of the street in order to give house-to-house supply.



It would further appear that a long line of iron plate along the sidewalk would be dangerous to foot passengers in frosty weather, and would interfere with present arrangement of gas lamps and the existing sub-pavement and street cellars.

No estimate of cost was given. The system would necessarily be an expensive one.

THE DELANY CABLE

FOR ELECTRIC LIGHTS, TELEGRAPHS, TELEPHONES AND ALL ELECTRICAL CONDUCTORS.

Description of the Inventor Edited by the Examiners.

("C." of the Section's Classification.)

This cable may comprise any number of conductors desired, and of any size required. When a single conductor is used, a bare or cotton-covered wire, insulated in any of the usual ways, is threaded through small disks or buttons of vitreous material, such as porcelain or glass, so that the conductor throughout its entire length is covered by the incombustible buttons which are about half an inch in length and one-eighth of an inch in thickness. The conductor thus surrounded is passed through a compound of insulating material and through a lead press machine which encloses the whole in a lead covering or pipe, so that, when finished, the cable or conductor is first enclosed in a braided covering saturated with an insulating compound, then surrounded by the incombustible disks or buttons, again covered with an insulating compound which is forced in hot as the lead pipe is formed around it. The latter filling occupies all the interstices and space between the conductor and the vitreous buttons and between the buttons and the pipe, thus leaving no air spaces and thereby preventing condensation of moisture. The incombustible material separating the conductor from the pipe, renders the transmission of the most powerful currents absolutely safe, since under no circumstances can the conductor come in electrical contact with the pipe. Should the conductor become heated the soluble insulating compound would be united more firmly, closing up any cracks that might have occurred from low temperature or contraction.

When a series of conductors are used they are all threaded through separate holes in the same disk or button, and thus mechanically separated from each other and from the pipe in which they are enclosed.

This cable is practically indestructible, as its durability is only limited to that of the enclosing pipe, which may be of lead or iron. When lead is used the cable may be constructed in lengths of one-quarter or half a mile without splicing, and coiled on a reel, the vitreous disks admitting of flexing to any extent necessary.

The conductors cannot become crossed, nor can they be grounded so long as the enclosing pipe remains intact. As the lead pipe is formed around the cable in a molten state, there is no seam, weld or joint throughout the entire length in each section.

All danger from fire in buildings is obviated. Rats cannot destroy the insulation and the cable may be laid in chimneys, ventilation or heating flues, or placed in the walls like gas or water pipes, with perfect security against interruption or damage, or the necessity for tearing out the walls for repairs of any kind.

Three tests of this cable were made at the International Electrical Exhibition, for the purpose of ascertaining the effect of powerful currents on the insulation. These tests were made under the direction of Capt. de Wolski, Chairman of the Committee on Underground Conductors. The first consisted of placing a piece of cable about five feet in length so as to short-circuit the Hochhausen electro-plating dynamo-machine. Ths conductor, a single one, insulated as described in the beginning, was No. 4 Birmingham gauge copper wire. The dynamo-machine had an electro-motive force of two and one-half volts. A current of 600 amperes was passed through the cable for 20 minutes. The conductor was made red hot, but the insulation was uninjured, the melting of the filling-in compound being the only result of the experiment.

The second test was similar to the first, with this difference in the current—800 amperes were sent through the cable for 20 minutes. The wire became so hot that the vitreous disks surrounding it melted the lead covering, leaving the insulation uninjured.

The third test was with the conductor inclosed in an iron instead of lead covering. When sufficient current could not be passed through the conductor to cause any effect other than the melting of the filling compound and charring of the braided covering on the wire. The conductor was perfectly secure in its insulated separation from the pipe and consequently free from all danger.

This single conductor, insulated and inclosed as described, ready for use in the ground or elsewhere, can be furnished for 22 cents per foot. Six separate conductors of No. 16 copper wire, for telegraph or telephone use, and covered in a like manner, will cost the same amount.

The foregoing report is respectfully submitted by

F. D. de WOLSKI (*Chairman*),
PERSIFOR FRAZER.
LUTHER L. CHENEY.
Examiners of Section XVIII.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884
OF THE
FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,
FOR THE
PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTIONS XIX, XXIV & XXVII,

ELECTRIC TELEGRAPHS. ELECTRO-DENTAL APPARATUS. APPLICATIONS OF ELECTRICITY TO WARFARE.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED
AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN
INSTITUTE, MARCH, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

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WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XIX.—TELEGRAPHIC SYSTEMS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XIX, on Telegraphic Systems.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XIX (on Telegraphic Systems), respectfully present the following report.

FRANK L. POPE (*Ch'n*),
Examiners of Section XIX.

PHILADELPHIA, *December*, 1884.

REPORT ON TELEGRAPHS.

(SECTION XIX.)

I. TELEGRAPHIC SYSTEMS.

The different methods which have been from time to time devised for increasing the working capacity of a single telegraph wire by enabling it to simultaneously transmit two or more communications in the same or opposite directions are technically termed duplex, quadruplex and multiplex systems. Four telegraphic systems of this general character are exhibited: the synchronous-multiplex telegraphs of T. A. Edison and P. B. Delany, the well known quadruplex of Edison, and the Morse-harmonic duplex of Elisha Gray. Each of these systems except the first is in commercial use in the United States. That of Mr. Delany is of quite recent introduction, and for this reason as well as for its remarkable ingenuity, both in conception and execution, deserves special attention.

The possibility of employing a single conductor for the simultaneous transmission of two or more sets of telegraphic signals appears to have originated with Moses G. Farmer, of Boston, Massachusetts, about the year 1852.* Mr. Farmer attached to each end of the line a rapidly revolving commutator or distributor. The two distributors when caused to revolve synchronously and in unison, served to bring the line successively and simultaneously into connection with a corresponding series of short branches at each terminus, in each of which branches ordinary telegraphic apparatus was inserted and operated in the usual manner. Thus the current through each pair of corresponding branches at either station, while apparently continuous, actually consisted of intermittent but rapidly recurring synchronous pulsations. Mr. Farmer successfully experimented upon a small scale, upon the wires of the municipal telegraphic lines of Boston, in 1852. Nothing of permanent value, however, resulted from the experiments at that date, the difficulty of maintaining the absolute synchronism required for operating for any considerable length of time being apparently insuperable. Many subsequent inventors have sought to render this method practically useful; among others Mr. Edison, whose apparatus is exhibited and will be hereinafter referred to. The apparatus of Mr.

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* United States Patent, No. 9,634, March 29, 1853.

Delany, now for the first time publicly shown in operation, appears to realize to the utmost the possibilities inherent in this method. The methods of multiple transmission which thus far have found the widest practical application, of which Edison's quadruplex system is a well known example, are based upon a wholly different principle, that of differential or balanced currents or magnetic forces, which may properly be considered an outgrowth of the invention of Dr. Wilhelm Gintl, of Austria, in 1853.* Still another system is based upon the discovery of Elisha Gray † that two or more sets of harmonic vibrations may be set up at the same time in a continuous electric current, and separated from each other at the receiving station. Upon this discovery Mr. Gray has based a system of harmonic multiple telegraphy. The present exhibition therefore affords practical examples of each one of the three fundamental principles upon one of which every multiple telegraph has hitherto been founded, viz: the *synchronous*, the *differential* and the *harmonic*.

THE DELANY SYNCHRONOUS-MULTIPLE SYSTEM.

This system is founded upon an invention of Paul Lacour, of Denmark, made prior to 1878, and termed the "phonic wheel."‡ The phonic wheel is employed for regulating and rendering approximately synchronous the revolutions of the distributors at opposite ends of the line. The two principal difficulties which Mr. Delany has been obliged to overcome in reducing this system to practice are, *first*, the maintenance of the necessary synchronism: and *second*, the utilization in the formation of signals, of exceedingly short pulsations of electricity.

Speaking in general terms, it may be stated that Mr. Delany has, in our opinion absolutely overcome the first of these difficulties, by the happy conception of providing for an automatic mutual interchange of correcting pulsations at frequent intervals between the separate instruments, in case there exists any tendency towards deviation from the normal speed, the latter being approximately controlled by the vibrations of a tuning fork, acting electro-magnetically upon the phonic wheel. It has been conclusively demonstrated that synchronism may be maintained continuously for days, between two instruments at opposite terminals of a telegraph line, without a variation exceeding the six hundredth part of a second.

---

* Prescott. Electricity and Electrical Telegraphy, p. 769.

† Journal of American Electrical Society, 1875. Prescott's Electricity, p. 876.

‡ United States Patent, No. 203,423, May 7, 1878.

The effective rate of speed with which the apparatus can be operated, or more properly, the actual transmitting capacity of a given conductor equipped with this apparatus, depends, *first*, upon the rapidity with which successive impulses can be made to traverse a line, while preserving to each impulse a degree of strength sufficient to produce the movement of the armature of a relay at the receiving station, and *second*, upon the mechanism by which these pulsations may be made available in the production of arbitrary signals representing letters and words.

The rapidity with which the successive electrical pulsations can be produced at the distant end of a given telegraphic line, is inversely in proportion to the resistance and electro-static capacity per unit of length of the insulated conductor and inversely as the square of its length.* Other things being equal, the rapidity is greatly augmented by forming a connection directly between the line and the earth at each end of the line between each two pulsations. This operation is provided for in Mr. Delany's apparatus. The employment of pole-changing or double-current keys and polarized receiving instruments (a suggestion understood to be due to Mr. E. A. Calahan, who has been associated with Mr. Delany in the development of the invention), enables short and rapid pulsations to be utilized to the fullest extent in the formation of the signals of the conventional telegraphic code. For a detailed description of the apparatus we would refer to a recently published paper by Professor E. J. Houston.†

The actual performance of the apparatus, during the tests made by the committee, over 200 miles of line (from Philadelphia to Jersey City and return) was eminently satisfactory. The rate of rotation of the distributors was stated by the exhibitor to be 170 revolutions per minute, the same as that of the instruments in daily commercial use between Boston and Providence, a distance of about fifty miles. At this rate of speed the duration of each contact was 0·0021 seconds. With the apparatus arranged for six distinct communications, either all in the same direction, or partly in one direction and partly in the other, we ascertained by actual trial that communications could be received with distinctness upon the ordinary Morse sounder at a rate of from thirty to forty words per minute. With the apparatus arranged for twelve communications a rate of twenty words per minute was attained with equal facility. The application of the system, however, is not limited to the simultaneous transmission of twelve messages, for by the use of a type-printer especially designed for the purpose (specimens of which are exhibited with the other apparatus) as many as seventy-two independent circuits may be actuated. This is necessarily effected at a less rate of speed, although it is quite sufficient to enable each of the separate users of the line to transmit during six hours at least 100 dispatches of the average length, a speed which may be increased proportionately when desired, by placing at the disposal of the user one thirty-sixth or one eighteenth instead of one seventy-second of the entire capacity of the line.

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* Sir William Thomson. Proceedings of Royal Society, May 24, 1855.

† "Journal of the Franklin Institute," January, 1884.

EDISON'S SYNCHRONOUS-MULTIPLE TELEGRAPH.

This system is exhibited in Mr. Edison's collection of apparatus illustrating his inventions, and was devised by him in 1876.[*] It consists of two heavy tuning forks, one of which is placed at each end of the line, and kept in vibration by an electro-magnet and automatic circuit breaker or rheotome. By meams of adjustable sliding weights upon the forks; their vibrations may be made synchronous. Suitable contact springs are provided, which are moved by the vibrations of the forks, and by means of these the main wire connecting the two stations is simultaneously transferred from one to another of a succession of short branches at each terminal station, each branch containing an ordinary telegraphic apparatus. This apparatus is of historical interest, as marking an important step in the progress of invention intermediate between the original plan of Mr. Farmer to which we have already referred and the perfected apparatus of Mr. Delany, Mr. Edison we believe being the first to make use of tuning forks for controlling the synchronous transfer of the main line from one branch to another at the terminals. The apparatus of Mr. Edison has met with no practical application, a circumstance which is doubtless due among other things, to the lack of any automatic means of correcting the synchronism of the forks.

[‡] U. S. Patent, No. 200,993, March 5, 1878.

EDISON'S QUADRUPLEX TELEGRAPH.

The original form of this well-known apparatus is shown in Mr. Edison's collection. With some modifications it is now in extensive use by the Western Union Telegraph Company throughout the United States. To convey some idea of the usefulness and commercial value of this apparatus it is sufficient to say that it has increased the telegraphic facilities of the Western Union Company to an extent equivalent to the addition of 50,000 miles of wire. It is also employed to a considerable extent in Europe. The principle of differential or balanced circuits upon which it is constructed and operated is so well-known as to require no detailed description in this report.

GRAY'S HARMONIC DUPLEX.

This ingenious and effective system enables the capacity of an ordinary telegraph line to be doubled or trebled by an addition of a small amount of supplementary apparatus. The principle upon which it acts is as follows: If we take the case of an ordinary telegraph line, operated according to what is generally known as American Morse system, in which the line is traversed by a normally closed circuit passing through a number of stations, both way and terminal, each of which is provided with a circuit-breaking key for transmitting signals and an electro-magnet for receiving them. The alternate opening and closing of any one of the keys in the circuit produces corresponding signals upon all the electro-magnets. According to Mr. Gray's invention one or more additional sets of signals are superposed upon the continuous current, by means of vibrating harmonic transmitters, these produce rapidly recurring series of rhythmical vibrations, by slightly increasing and decreasing the strength of the current in rapid alternation. These vibrations are responded to by one or more electro-magnets, each having a tuned reed armature. Thus it will be seen that a second and a third series of signals may each be transmitted by a key controlling a particular set of vibrations, and received upon correspondingly tuned armatures, without in the least affecting the ordinary Morse instruments. Inasmuch, however, as the line is entirely severed and interrupted by the operation of the keys as ordinarily used, it is necessary to bridge over the gap formed by the open key, in such a manner that the harmonic vibrations will not be interrupted. This is done by connecting the terminals of the key through an artificial resistance, which is sufficiently great not to permit enough current to pass to operate the ordinary telegraph instruments, although the harmonic vibrations continue to pass through it freely especially, when an electro-static condenser is provided in addition to the resistance. This system is well adapted for the railway service, inasmuch as the harmonic communication may at a small expense be applied to the ordinary Morse circuit employed by all railroads for regulating the movements of trains, it may be used as a through communication for the general business of the officers of the railroad, or if desired, for ordinary commercial telegraph business, without incurring the expense of an additional wire, or the inconveniences necessarily entailed by any alteration in the established method of operation.

EDISON'S AUTOMATIC-CHEMICAL ROMAN LETTER TELEGRAPH.

This system, which is also exhibited by Mr. Edison, is an improvement upon the well-known typo-telegraph of Bonnelli. Like the Bonnelli system, five independent line wires are employed, and the record is made in plain Roman letters upon chemically prepared paper. The receiving instrument is in fact essentially the same as that of Bonnelli, except that the paper is carried forward by a small electro-motor instead of by clock-work. The method of transmission, however, is a novel one, and possesses some points worthy of notice. The communications to be transmitted are first prepared by means of a punching machine operated by a piano key-board. Each key, when depressed, selects from a group of twenty-five cylindrical punches arranged in a solid square, the necessary punches to form the corresponding outline of a Roman letter, and this group of selected punches is, by appropriate mechanism, driven through a strip of paper, thus forming the required letter from lines of circular perforations suitably arranged, like the perforations of a stencil pattern. The strip containing the message formed of these perforated characters is then caused to pass underneath a series of five styluses, placed side by side in a transverse row, to each of which styluses one of the five line wires are attached. As each perforation passes beneath the point of its corresponding stylus, the latter drops through it, and closes the circuit upon a metallic roller underneath, thus producing a mark upon the chemical paper at the receiving instrument in the same relative position upon the tape that the corresponding perforation is in the pattern strip.

This apparatus was shown in actual operation upon a short line and its performance appeared to be excellent. The extraordinary rapidity with which messages can be transmitted and recorded upon the tape, far exceeding that attainable by any possible system of mechanical printing, would seem to indicate that this apparatus may yet prove to be of great value for market quotation and commercial news telegraph lines. These lines being generally of no great length, the increased number of wires required would not constitute a very serious objection.

EDISON AUTOMATIC-CHEMICAL TELEGRAPH.

This apparatus is an improvement upon the well-known chemical telegraph of Alexander Bain. Aside from numerous improvements in mechanical construction of the apparatus, the leading feature of novelty is in the organization of the perforating apparatus, which is provided with two sets of punches whereby the conventional alphabet may be formed by means of a double set of circular perforations arranged in two rows. Means are provided whereby upon a depression of a lettered key upon a piano key-board, the appropriate punches which form the corresponding character of the telegraph alphabet are selected and forced through the paper, thus forming a complete character by a single depression of the proper key. The perforation can be effected with great rapidity, a speed of fifty or sixty words per minute having frequently been attained by expert operators. The strip thus prepared is passed through a circuit-closing transmitter and the record is made in the usual manner upon chemical paper. A speed of transmission of 1,000 words per minute has been attained by this apparatus upon a wire between New York and Philadelphia, 100 miles in length. This system was at one time in commercial use to a considerable extent in this country, but has been abandoned, for reasons probably due more to peculiarities in the commercial requirements of American telegraphy than to any inherent difficulties in the operation of the mechanism itself. The automatic method of transmission, although full of promise, has in almost every instance failed to realize the expectations of its advocates, as a substitute for the ordinary process of manual transmission. This difficulty, whatever it may be, is inherent in the principle itself and is not properly chargeable to defects in the operation of the apparatus.

EDISON'S AUTOGRAPHIC TELEGRAPH.

This apparatus is included as a portion of Mr. Edison's exhibit. It was not set up in such manner that its construction or mode of operation could be examined, and we are therefore unable to report upon it. It may perhaps be proper to say, that the autographic system for the transmission of communications in fac-simile, would seem to afford one of the most promising fields for the labors of future improvers of the telegraph. It is apparently in this direction, if any, that we must look for the future solution of the problem of cheap telegraphy. It will be readily understood that if an efficient system were invented by which the original message, as written by the sender, could be placed in a machine and a fac-simile of it instantly produced by the action of electricity at a distant station, and this by automatic machinery without the intervention of human hands, the actual cost of performing the service would be but the merest trifle. Yet there is apparently no obstacle in the way of obtaining this result which we may not hope to see overcome, sooner or later, by the genius and perseverence of our inventors.

II.—Telegraphic Apparatus.

THE WESTERN ELECTRIC COMPANY.

This company exhibits a complete assortment of telegraphic instruments and apparatus of all kinds, manufactured in their workshops at Chicago, New York and Boston. Among the apparatus worthy of special commendation we mention the following:

REGISTER.

This register embodies several novel features which greatly add to its utility and convenience of manipulation. The mechanism is mounted upon a circular base in such form that the clock-work and paper reel may be covered by a movable glass shade, and thus completely protected from dust, while at the same time it presents a very ornamental and attractive appearance. The paper tape containing the record is made to pass out through an opening in the base beneath the glass cover. This instrument is constructed either for embossing the paper, or for marking with ink, as may be desired. A self-starting apparatus, of novel and effective design, is supplied, by which the clock-work is automatically started and stopped at the commencement and termination of a message without the assistance of the operator. This feature especially adapts this register for the fire-alarm, police or messenger service, as well as for private telegraph lines worked upon the Morse system. This instrument is worthy of the highest praise, not only for the elegance of its design and finish, but for its effectiveness, durability and perfect adaptation to the purposes for which it is intended.

It is interesting to compare this latest model of the telegraphic register with one of the first pair of original instruments which is exhibited in the historical department. This pair of instruments was constructed, in 1843, under the personal supervision of Alfred Vail, who was intimately associated with Professor Morse, both in the invention and in the introduction of the American telegraph, a considerable part of the mechanical work having been done by his own hands. Vail invented the combination of mechanism for registering, consisting of the electro-magnet, marking point and grooved roller, an apparatus so simple and effective that it has never yet been superseded. There appears also to be little doubt that to Vail is also justly due the credit of devising the conventional alphabet of dots and lines, which has become the universal telegraph language of the world.

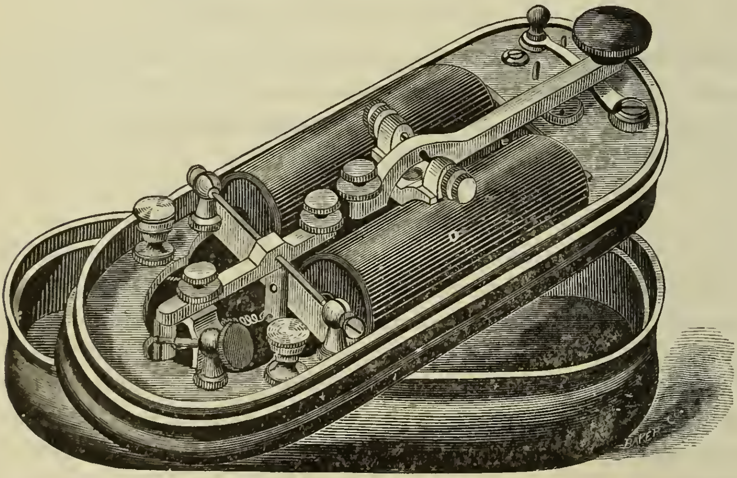

FIG. 1.

The close resemblance between the original and the modern instruments, except in certain matters of comparatively unimportant detail, becomes strikingly apparent upon a critical examination. The electro-magnet, lever, retracting spring, steel marking point, grooved roller and clock-work for moving the paper, are almost identical. The driving weight of the original system has been replaced by a coiled spring; the self-starting device by another of more effective construction, and the relative position of the parts has been somewhat changed, but the instrument nevertheless remains, to all intents and purposes, the same as when it first came from the hands of Vail, more than 40 years ago.

POCKET RELAY.

This is a portable instrument, much used by line repairers and telegraphic operators in the military service (Fig. 1). It is enclosed in an oval hard-rubber case, about four inches by two, and weighs but a few ounces. Notwithstanding the small size of this case, it contains a complete telegraphic apparatus, consisting of a key and sounder, for sending and receiving messages. The electro-magnet is large enough to be thoroughly efficient; the key is of sufficient size to be convenient of manipulation, and the sound of the receiving instrument is remarkably loud and clear. It is a matter of some interest to contrast this exceedingly minute and well-finished apparatus with that used on Morse's first line, in 1844, and at that time supposed to be indispensable, consisting of a receiving instrument, of which the electro-magnet alone weighed 180 pounds!

THE LEWIS LEGLESS STEEL LEVER KEY.

This is a well-designed and well-finished transmitting key (Fig. 2).

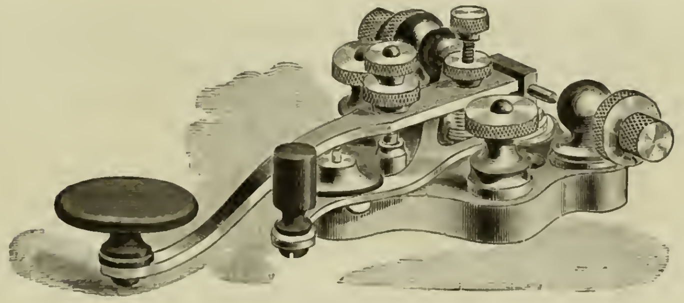

FIG. 2.

It has a steel lever, combining lightness with strength, together with a certain desirable degree of elasticity, and having its terminal binding posts upon the top of the base, so that it may be set up without the necessity of boring holes through the table, a provision which is often found to be very convenient in practice.

STANDARD MORSE SOUNDER.

This sounder is provided with an extra thumb-nut on the adjusting bar, to maintain the spring at a constant tension. This is a minor feature, of much utility, which has been generally neglected by all manufacturers of such apparatus, and we therefore think it deserving of special mention.

GRAY'S PATENT CUT-OUT, LIGHTNING ARRESTER AND GROUND SWITCH.

This is a most convenient and effective device for connecting the instruments in a telegraph office with the main line and disconnecting them at pleasure (Fig. 3). The apparatus is so arranged that this can be done in an instant, and without causing any interruption of the line. It is obviously far less liable to get out of order than the wedge-switch and divided plug usually employed for the same purpose, and is certainly no less convenient in its manipulation.

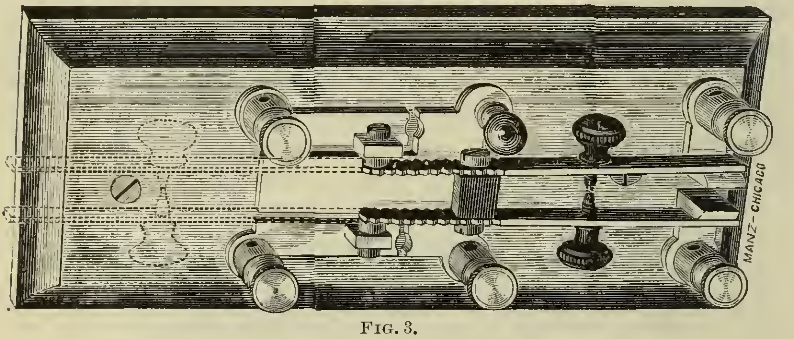

FIG. 3.

PRIVATE LINE INSTRUMENT.

This apparatus comprises a full-sized and well-finished Morse key and sounder (Fig. 4), mounted upon a metallic base and provided with binding-screws, ready for immediate connection with the line. It is adapted to work a line of any length up to 20 or 30 miles. This instrument is no less remarkable for its efficiency than for its low cost. It contains all the essential apparatus for a telegraph office except the battery, and is sold for $4.

The Western Electric Company also exhibit a complete assortment of modern telegraphic apparatus and fixtures, which although possessing no novelty of design deserve particular mention for their excellence of finish and careful adaptation for use. All the instruments shown by this Company are handsomely nickel-plated and present a very attractive appearance.

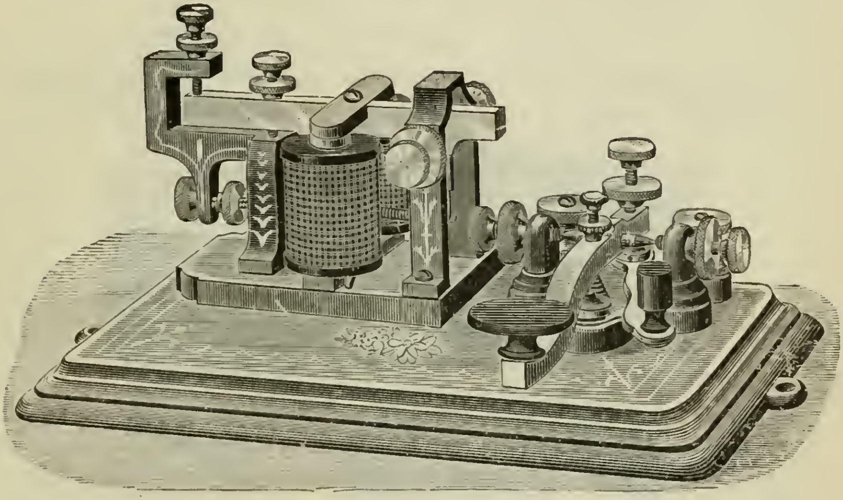

FIG. 4.

THE STEVENS TOP CONTACT KEY.

This is an improved construction of the transmitting key of the Morse telegraph, invented by E. G. Stevens, of Cleveland, Ohio, and exhibited by the Standard Electrical Works of Cincinnati, Ohio. The contact point is at the extreme rear end of the lever, and when raised by the depression of the knob of the key to form a signal, impinges upon a flexible arched arm. The object of this arrangement is to avoid the concussion produced by the operation of the ordinary key in striking downwards upon a solid anvil which is rigidly secured to the table. Such an improvement has been regarded by many practical operators as a desideratum; as with many persons the concussion of the lever is exceedingly fatiguing to the hand, when working for many hours continuously. This is thought by many to be one of the principle causes of the disease known as "operators paralysis." This modification has been introduced without giving rise to any additional complication or other objection, and we commend it as an improvement of value, for the reasons mentioned.

PARTICK AND CARTER.

This firm exhibit a complete assortment of telegraphic apparatus adapted for all ordinary uses, all of which are well constructed and handsomely designed. Among the instruments presenting special points of excellence we would mention the following:

RUBBER CASE POCKET RELAY.

This is a small and compact portable instrument for line repairers and military operators, and is enclosed in an oblong hard rubber case with circular ends. It is about four inches in length including the case, and weighs but a few ounces. The transmitting key is of unusually large size in proportion to the remainder of the apparatus, and this, as well as the sounding mechanism, is very ingeniously arranged in a compact form so that although very little space is occupied, the operation of the mechanism is remarkably effective.

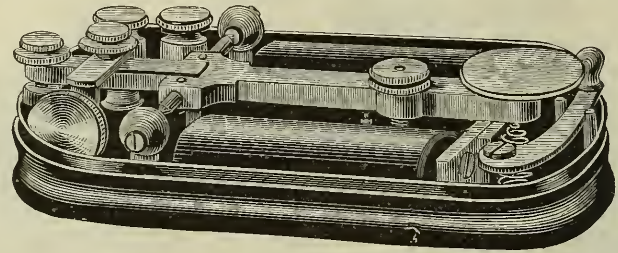

FIG. 5.

STANDARD AMERICAN REGISTER.

This is an accurately constructed and well finished form of embossing register.

A special feature is the arched bridge upon which the limiting stops of the pen-lever are mounted, which enables the instrument to be used as a sounder with equal facility, whether or not the operation of recording is going on at the same time.

NEW WRECKING INSTRUMENT.

This is a compact portable instrument (Fig. 7) in which all the working parts are of full size, but are so disposed as to occupy a minimum amount of space. It is much used in the railroad service for establishing temporary offices at points along the line, as in case of an accident obstructing traffic upon the road. It is desirable that an instrument of this class should operate with all the convenience, facility and accuracy of a standard instrument, and yet be capable of being transported from place to place without inconvenience. This instrument is unusually well designed and merits special commendation.

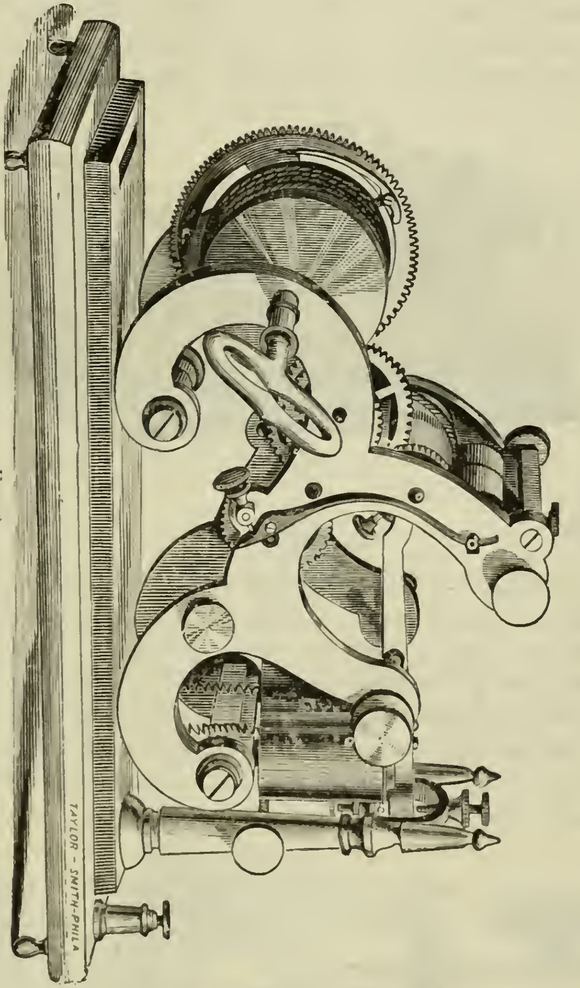

Fig. 6.

THE ACME STEEL LEVER KEY.

The lever of this key (Fig. 8) is stamped from sheet steel instead of being of cast brass as in the old form of key. This gives the lever great strength, together with a certain slight degree of elasticity which is regarded as important; while the weight to be moved is very small, a matter of great importance, as the operator in transmitting at the maximum speed of forty words per minute is required to make no less than fourteen or fifteen distinct movements of the hand per second and to maintain this continuously for hours. The design of this key is tasteful and the finish excellent. The binding posts for connecting the wires are placed upon the upper side of the base.

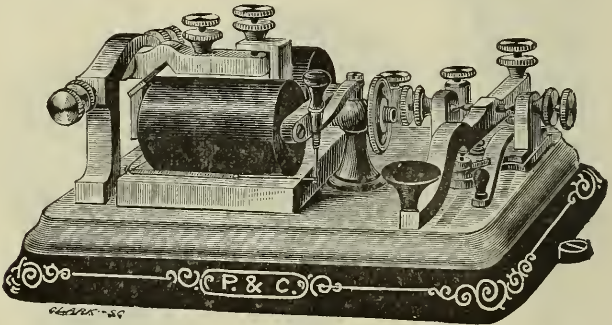

FIG. 7.

THE LATTIG KEY.

This key (Fig. 9) is the invention of a practical operator, and is provided with a supplementary or auxiliary circuit-breaking lever by which the separation between the contact points at the opening of the key is very largely increased, although the play of the key-lever itself is no greater than in the ordinary form. We regard this key as well adapted for use on lines on which a strong current is employed, and which have a great number of way-stations, conditions which exist upon many of the railway service lines.

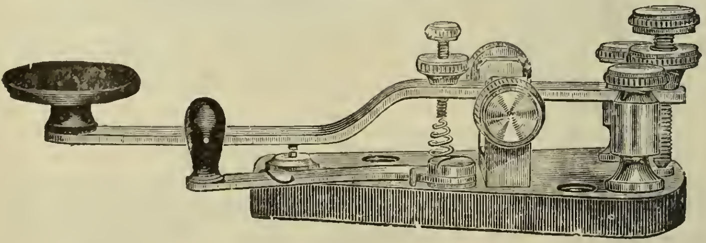

FIG. 8.

THE CUMMING PERIPHERY CONTACT.

This invention, exhibited by Cumming & Brinkerhoff, 219 E. Eighteenth street, New York, is an improved construction of contacts or electrodes for telegraphic circuit-breakers such as keys or relays. A key is exhibited (Fig. 10) which illustrates the application of the invention, which consists of two revolving discs or wheels which form the contacts, each of which is beveled down to a narrow edge on its periphery. The two disc electrodes are placed at right angles to each other, so that the actual contact is formed between two very minute surfaces. This form of contact appears to possess certain advantages, among which may be mentioned the adjustability of the discs, which enables the point of contact to be changed at pleasure. Dust is also prevented from accumulating upon the contacts. There is a certain

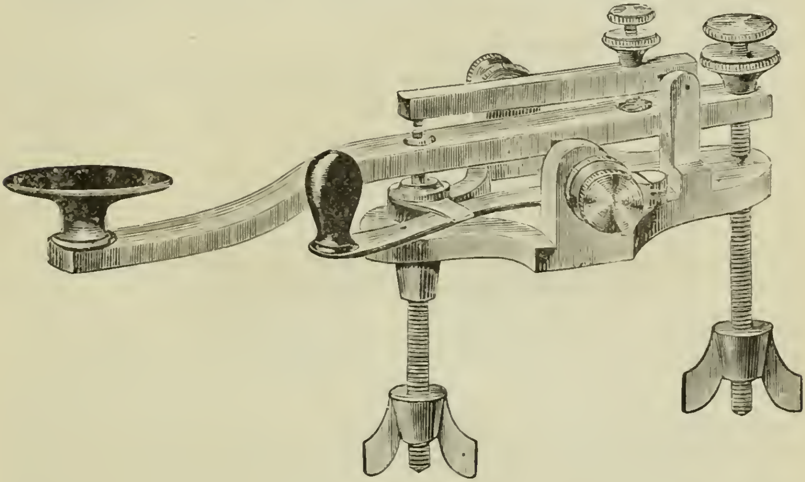
FIG. 9

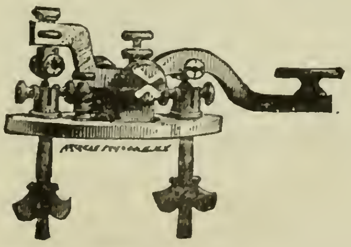
FIG. 10.

elasticity in the system which avoids the concussion of the ordinary key upon a solid anvil which is found by experience to be so injurious to the muscles of the hand of the operator. A practical trial of the key by members of the committee who have been practical telegraphic operators, shows that it is an extremely pleasant one to manipulate. The same device has also been applied to the pole-changer for the transmitting apparatus in the quadruplex telegraph, on which currents of unusual strength from a dynamo-electric machine are employed.

The exhibitors of this invention give the following explanation of the theory of its operation :

In the ordinary contact, which is made by the flat ends of two platinum wires *J* and *K* (Fig 11), the electric current tends to jump the intervening space (thereby forming an electric arc), for the two contact surfaces not being mathematically parallel can meet only at one point. Let this be at or near the centre *C*, the currents on the surface from *A* or *B* curve around to this point, approaching and attracting each other at all points, but joining only at one. If the contact is on one edge *t* the currents of *D* and *E*, in passing from *G* or *H* to *t*, must mutually attract one another; and the nearer *G* and *H* are to each other without touching the more liable the key is to "stick." In the case of two sharp cones or needles approximating as in Fig. 12, the currents pass almost straight to the apices *V* and *X* from *O*, *P*, *R*, and *S*, and therefore meet with no interference. The nearest approach to the needle point in practical application is the Cumming Periphery Contact of two discs set at right angles, as shown in Fig. 10.

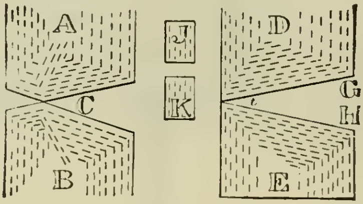

FIG. 11.

THE VULCANIZED FIBRE COMPANY.

This company whose works are situated at Wilmington, Delaware, exhibits a number of samples of telegraph apparatus of different kinds manufactured by Patrick and Carter, in which the material commercially known as "vulcanized fibre" has been utilized as an insulating material, where such material is required, such as cases, bobbins and covers for electro-magnetic coils, etc.

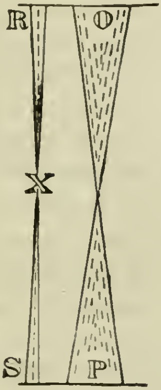

FIG. 12.

This material seems to possess many desirable characteristics for this purpose. It is made in three colors, red, white and black. It is much cheaper than vulcanized rubber, takes an excellent polish and withstands heat, very much better than rubber. It is an excellent insulator, except that in very damp places it absorbs moisture to some extent. This, however, does not affect its value for telegraphic apparatus, which is always carefully protected from dampness. We consider it admirably adapted for the purposes to which it has been applied in the exhibit under consideration.

M'CAUSLAND'S PRINTING TELEGRAPH.

This apparatus is designed for the rapid printing of quotations of the markets and exchanges, according to a system in extensive use in the larger cities of the United States.

Two line wires are employed, one for bringing the type wheel into position and the other for printing the successive letters as they are brought into position. The mechanism for advancing the type-wheel by the to-and-fro motion of the armature of an electro-magnet is a prominent characteristic of the machine. In the instrument now in general use this is effected by a driving escapement, consisting of a ratchet or pawl attached to and moved by the armature, and a ratchet-wheel with inclined teeth fixed on the type-wheel shaft. By this mechanism, an intermittent advance motion of rotation is communicated to the type-wheel shaft. In the McCauseland machine this form of escapement is replaced by a small crank, which is caused to revolve by the reciprocating motion of the armature, and has upon its axis a pinion which engages with a large toothed wheel upon the type-wheel shaft. The application of this mechanism is exceedingly novel and ingenious, and would seem to possess at least one important advantage namely: that the motion of the type-wheel in passing from one letter to another is continuous and not intermittent. It thus not only utilizes the magnetic power (which is barely sufficient at most) to great advantage, as the type-wheel does not have to be started from a position of rest at each pulsation, but the momentum of the type-wheel tends to assist the action of the electro-magnet in case of an imperfect electrical pulsation. The platen for printing from either one of two parallel type-wheels, is an exceedingly novel, simple and efficient device. The type-wheel magnet is double, consisting of two magnets placed side by side and acting simultaneously upon one and the same armature. The electric current is divided upon entering the instrument between two branch circuits, half going through one magnet and half through the other. The inventor conceives that by this arrangement the force of the electrical current is compounded and that greater magnetic force is produced in all cases from a given current. This, however, depends entirely upon the ratio of the several resistances of the electro-magnet the line and the battery. The assumption is true under the particular conditions under which the instrument was exhibited, namely, a battery of small resistance and a line of inappreciable resistance. It would not be true under the conditions which must necessarily exist in actual service, and we do not regard this detail of arrangement as one possessing any value.

EDISON'S EMBOSSING TRANSLATING TELEGRAPH.

This apparatus is designed for the automatic retransmission of telegraphic messages at transfer stations. This work is usually performed by automatic repeaters, in which the receiving instrument of the one line acts as a key to re-write the communication, letter by letter, upon another line. In case it is not convenient to do this, the message is copied in the usual manner by the receiving operator, and then handed to another operator, to be resent upon the second line. Mr. Edison's apparatus is designed to stereotype the received message upon paper in telegraphic characters. This stereotype may be used at any time thereafter for the automatic retransmission of its contents upon the same or another line.

The mechanism is very simple, consisting of a horizontal circular brass plate, having spiral grooves engraved upon its upper surface, which plate is capable of being revolved by an electric-motor. A sheet of soft paper is fastened upon the surface of the plate and revolves with it, so that the telegraphic characters, as received, may be embossed upon it by a stylus working into the spiral groove, in the manner of the ordinary telegraphic register. This circular sheet of paper, with the message embossed upon it in spiral lines, forms a stereotype, which may be used at any time to retransmit the message, by placing it upon the same or a similar plate and permitting the stylus to follow the indentations, by which a proper motion is imparted to it for making and breaking the circuit upon the second line, and thus the original signals are reproduced without possibility of error.

EDISON'S MOTOGRAPH RELAY.

This is a telegraphic receiving instrument, which is operated without the aid of electro-magnetism. It is based upon the fact, first made known by Mr. Edison, that an electric current passing from one to the other of two surfaces, in frictional contact with each other, materially diminishes the coefficient of friction. A small electric motor causes a cylinder of chalk to revolve against a rubber, to which rubber is attached the circuit-breaker by means of which the local receiving instrument is actuated. When no current is passing through the main line, the action of the friction tends to drag the circuit-breaker against its rear contact. As soon as the current flows, the friction is diminished to such an extent that it is overpowered by an antagonistic spring, which draws the circuit-breaker into contact with the stop which closes the local circuit. This is a highly ingenious apparatus, and is said to be capable of recording signals with much greater rapidity than any electro-magnetic instrument hitherto devised. It has not, however, been applied in practical use.

Here follows a description of the advantages of the use of the Type Writer for reproducing the messages received at the various telegraph stations.

For various reasons, among which, is the fact that the advantage could only be claimed for the reception of messages on telegraphic instruments which do not print. The Editing Committee has judged it expedient to omit this paragraph.—(Ed. Com.)

Respectfully submitted by

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Chas. J. Shain, H. W. Sellers,
Wm. H. Greene, Hugo Bilgram,
E. Alex. Scott, John W. Nystrom.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIV.—ELECTRO-DENTAL APPARATUS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXIV, on Electro-Dental Apparatus.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXIV (on Electro-Dental Apparatus), respectfully present the following report.

J. FOSTER FLAGG, D.D.S., (*Ch'n. Section XXIV.*)

PHILADELPHIA, *December*, 1884.

ELECTRO-DENTAL APPARATUS.

This Section finds presented for its examination:

1st. The Bonwill Electro-Magnetic Mallet.

2d. The Dental Helix and Dental Electrode.

3d. The Electric Mouth Lamp.

4th. Numerous small Electric Motors, running either by dynamic or voltaic current, and adapted for dental use.

I. THE BONWILL ELECTRO-MAGNETIC MALLET.

[The Examiners here give a statement of facts and inferences bearing on the history of the application of electricity to the production of mechanical apparatus for treating the teeth, in which the services of Dr. Bonwill, as the originator of this type of apparatus, are set forth.—ED. COM.]

The dental engine of Dr. Bonwill, run either by foot or motor is claimed to be the first devised, and it is claimed that, with the present improvements, it is an imitation of the human arm and wrist joint. It is capable of exceedingly high speed and the utmost delicacy of movement, and is of extended range, both as to power and application.

The surgical engine is the first ever devised and made *truly* practical.

It is a duplicate of the dental engine, with the addition of a multiplying attachment to give increased speed and power, and to enable the surgeon to be entirely free from any pedal movement, the assistant at the crank driving it with that great power which is needed in the heavy and prolonged operations on the human bones.

Its great velocity makes it more sure and steady in the surgeon's hand while performing, with elegance and delicacy, operations that no human hand could possibly be capable of.

The mechanical mallet is the outgrowth of Dr. Bonwill's mechanical pen.

Resumé.—The electric mallet was conceived Feb. 27, 1867. It was improved upon until 1876, and placed in its present practical shape in 1879. The first three forms had the stroke governed by clock-work rachet, which would run an hour. Since 1871–1872, the automatic brake has been upon the instrument, and has been made very compact.

The first electric mallet weighed one pound, and had to be suspended from the ceiling; the last one weighs but five and a half ounces, and is used in the hand with perfect facility.

The dental engine dates, at least, as far back as 1869.

The surgical engine had its birth when the "human flexible arm" and the "universal chuck hand-piece" were devised, in 1876. The earlier forms of arm were not adapted for surgical work.

The mechanical mallet was brought out during 1876 and 1877.

Thus, through Dr. Bonwil, the dental profession is enabled to claim as among its gifts to suffering humanity these instruments, which do so much toward lessening labor, relieving pain.

II. The Dental Helix and Dental Electrode.

These instruments are made and exhibited by Mr. Otto Flemming, 1009 Arch street, Philadelphia, Pa.

The dental helix is a coil of wire, No. 20, Stub's gauge, fifty yards in length. This passes, in the usual manner, from a positive electrode, is coiled around a *covered* core of wires, and around a soft iron bar, to a rheotome stand-post. The current passes by this route through the rheotome to a screw-nib, and thence back to a negative electrode. The rheotome stand-post is utilized for a positive electrode, and two wires are attached to the main wire at a point upon the other side of the rheotome, and are led to a negative electrode.

By this shunting an induced current is obtained. Upon one of these two wires a switch is placed so that direct or open contact can be made; while into the circuit, upon the other, is introduced a water rheostat, by means of which, when the switch is open, such resistance is offered as permits the production of an interrupted current so delicate as to give, for its perceptible minimum, merely a slight taste (without sensation of interruption) when applied to the tip of the thoroughly moistened tongue.

This current can be gradually increased in strength until it becomes almost unendurably powerful.

From these possibilities this helix is especially adapted for operations upon the teeth, as the exquisite sensitiveness of the fifth pair of nerves (sensory to the teeth) is such as to render ordinary helix currents anything but agreeable.

This helix has, according to testimony presented from various persons, been very successfully used for the alleviation of pain, both in extraction of teeth and in the preparation of cavities of decay containing exquisitely sensitive tooth-bone.

The Dental Electrode.

This essential adjunct to the Dental Helix is a duplex electrode so arranged, shaped and connected that by the use of one hand it can be held and applied by the patient, thus securing a passage of current from the part to be operated upon to the hand of the patient, while the other hand of the patient is left free for the graduating of a precisely acceptable current, by means of the withdrawal or insertion of the core cover referred to above.

III. The Electric Mouth Lamp.

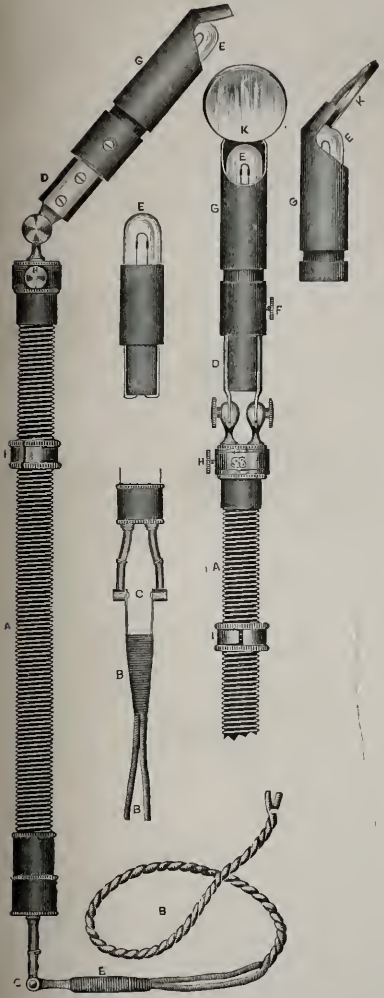
This appliance, in the exhibit of the S. S. White Dental Manufacturing Co., possesses for the dentist, so peculiar a value as to render it worthy of extended mention and minute description; not that its employment in this country of bright, clear daylight is frequently necessary, but that in almost all doubtful cases relating to pulp trouble and peridental irritation it gives a solution of such positiveness as to be simply invaluable.

The idea of illuminating the oral cavity is not claimed as original with this exhibit, but the various devices possessed only by the S. S. White lamp render it so eminently practical as to reflect great credit upon their Electrician, Mr. E. T. Starr. Of these we may speak; especially of the encasing of the lamp in a hard rubber non-conducting cylinder, with mirror attachment, so arranged that, by rotation of the casing, it completes the universal joint motion partially attained by the hinge which connects the lamp to the handle; and also of the "resistance handle;" which not only affords greatly increased safety against injuring the carbon loop of the lamp, but at the same time, so regulates the flow of current that any desired degree of illumination may be easily and promptly obtained.

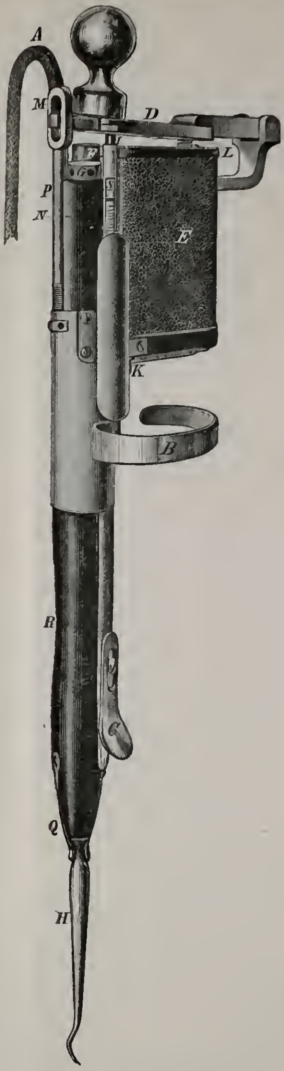
The effects resulting from the use of this lamp as an oral illuminator are peculiar and beautiful in the extreme; the teeth and gums are, if in a normal condition, singularly translucent, and the slightest deviations from the normal condition are wonderfully conspicuous.

Those who have used the lamp for the ordinary work of additional illumination during the preparation of cavities, and the introduction of filling material during dark days, report it as of marked assistance, and not so detrimental to sight as would be the effort of straining the unaided vision.

In use, the lamp is placed behind the object to be illuminated—that



The Electric Mouth Lamp.



Bonwill's Electro-Magnetic Mallet.

is, so that the object is interposed between the lamp and the eye of the observer. Thus, in examining the teeth the lamp is placed within the arch, so that its light falls upon the lingual or palatal surfaces of the teeth, while the eye of the operator is directed to the labial or buccal surfaces.

Description of the Cut.—The lamp *E* is an incandescent electric light mounted permanently in a non-conducting case or cylinder of hard rubber. The lamp is supplied with metal conductors which pass outside of the section of the case. The lamp case is carried in another hard-rubber cylinder, *D*, called the lamp-holder, which is also supplied with metal conductors fitting those on the lamp case, the two parts when adjusted being clamped together by the set-screw *F*, thus holding the lamp firmly in its socket. The conductors of the lamp-holder are connected to the handle, *A*, by hinged joints, so that almost any desired adjustment is readily secured. This handle is called a resistance handle because it is wrapped with wire of a low conducting power, by which, through the agency of the ring, *I*, the flow of the current is regulated. When the ring is placed at the end of the handle nearest to the battery-cord the resistance is reduced to the minimum and the current from the battery flows freely to the lamp. Sliding the ring to the opposite end of the handle compels the current to travel through the wire with which the handle is wrapped to the ring and back again, thus forming a resistance. The connection to the battery-cord, *B*, is made by the spring-coupling, *C*. A non-conductiing guard or shield, *G*, is placed over the lamp-globe for the double purpose of preventing the radiation of heat, and of directing the light to any point desired. At *H* is a screw for breaking the circuit. The circuit should be broken occasionally during a prolonged examination, and also whenever the lamp is not in use, to prevent its becoming so hot as to be unbearable in the mouth.

For the examination of posterior cavities in the teeth a mirror set at an angle of 45 degrees is attached to the end of the guard.

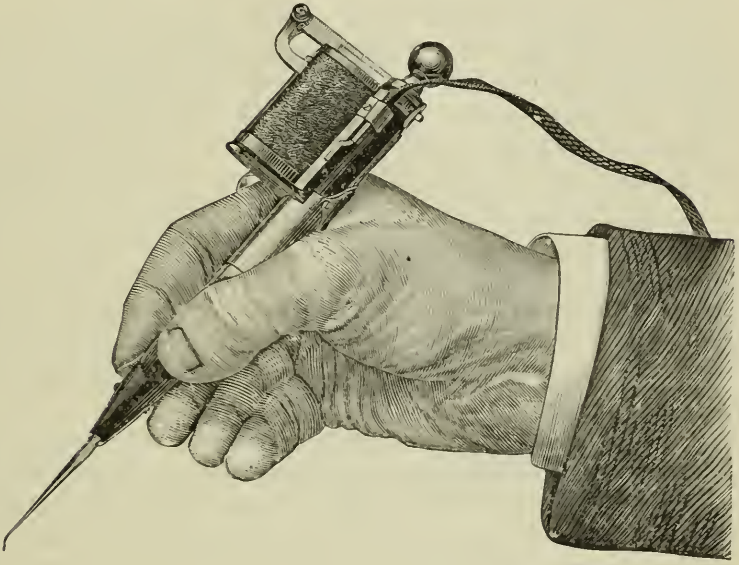
Battery Power—It has been found impossible so far to make the lamps of exactly equal power, but the variation is not great. To develop their full capacity requires about 3½ to 5 volts—say the current from three cells of a Bunsen battery. The cells of the battery supplied with the Electro-magnetic Mallet are excellent for the purpose, or three cells of any bichromate battery will answer.

Caution.—When connecting the lamp to the battery-cells always have the ring *I* (see cut) at the lamp end of the handle. If on turning on the current it is found insufficient to develop the full illuminating power of the lamp, slide the ring down the handle until the proper current is found. If through neglect of these precautions too much current be turned on it will probably destroy the carbon loop of the lamp.

In the S. S. White Dental Manufacturing Co.'s exhibit is also found a sample of the present perfected Bonwill electro-magnetic mallet, regarding which we publish a reprint of portions of their pamphlet upon this instrument.

How the Mallet is Operated.—Connect the instrument with the battery by passing the tubes attached to the silk mallet-cord *A*, over the two pins (on its reverse side, but not seen in the cut). Place the index finger through the ring *B*, resting upon the slide *C*; a very gentle pressure of the end of the finger upon the flange of the slide closes the circuit. The armature *D*, being thus attracted to the electro-magnets *E*, strikes upon the hard-rubber piston or plunger *F* (this is adjusted by the screw-nut *G*), against which rests the swell-end of the packing instrument *H*. Every time the armature is attracted to the magnets, it strikes the plunger *F*, and, at the same time, the rod of the interrupter *I*, thus breaking the circuit at *K*. The armature is then forced away from the magnets by the spring *L*, and is caught at *M*; the rod of the interrupter is carried back to its position by the recoil-spring *N*, which surrounds it, and the circuit is again closed,the instrument being thus kept in operation as long as pressure is continued upon the flange of the slide. The length of stroke of the armature or mallet is regulated, and the force of the blow to a certain extent controlled by the nut *O*, acting upon and firmly setting the rod *P*. The sound is lessened by the hard-rubber *M*, in the top of the slot. The packing or filling instrument *H*, which passes through the hand-piece, is controlled by the thumb through the opening *R*. The springs *Q* (one on each side of the hand-piece) keep the instrument in contact with the plunger *F*.

As each piece of properly-prepared foil is passed over the flame of alcohol and introduced into the cavity (either by an assistant with light-pointed foil-carriers, or by the operator), and simply attached to that already there, the instrument, *H*, being in position, the mallet should be set in operation by a slight pressure of the index finger upon the flange of the slide *C*. The instrument *H* should be held in place and guided very nearly in the same way as a pen or pencil.



One position of the hand in holding the electro-magnetic mallet is here illustrated, the thumb and index finger serving to steady and guide the instrument in the same way as a pen or pencil, and to close and open the circuit.

Some of its principle advantages are :

First.—The blow is delivered upon the packing instrument just at the point where its force is greatest.

Second.—The force of the blow upon the gold can at all times be controlled by the operator.

Third.—Properly used it condenses the gold thoroughly and evenly throughout the entire filling.

Fourth.—Gold may be placed against thin, frail walls, and made compact without fracturing the enamel.

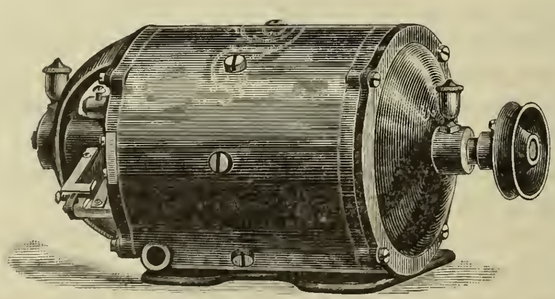
Fifth.—It saves the operator time and the fatigue attendant upon the use of a hand, automatic, or foot-power mallet.

Sixth.—When its operation is understood and the battery is kept in order according to instructions, the instrument does not require any more attention than a watch.

IV. ELECTRIC MOTORS ADAPTED FOR DENTAL USE, RUNNING BY EITHER DYNAMO OR VOLTAIC CURRENT.

A number of small motors (though for various reasons, not all that were upon exhibition) were presented for examination by this section. Among those tested, but three are deemed worthy of notice as specially adapted to the requirements of the dentist. These are the Edgerton, the Van De Poele and the Griscom or "Double Induction." Of these three motors as in comparison with all the others, we can say that they are very greatly superior. In comparing these three motors with each other the accomplishment of our desire to do full justice is more difficult, inasmuch as a $15 instrument is placed in competition with a $25, and a $30 instrument. We can, therefore, only give results, and with the few necessary comments for and against each motor, leave the decision as to positive superiority to be governed by the requirements of each individual demand.

1st. *The Edgerton Motor*, weighing twenty-two pounds, and costing $30, gave decidedly the most work under an electro-motive force of 5 volts. If, therefore, the weight of the motor was not objectionable, and the price was not too great, there would be found with it the decided advantage of capability with the expense and care of but three, or at most, four cells of battery. It was also found that with 8½ volts (five cells) an amount of power was given which far exceeded the limits of dental requirements. For these reasons the Edgerton motor was ranked as *first*.



The Edgerton Motor.

2d. *The Van De Poele Motor*, weighing nine pounds ten ounces, and costing $25 gave a very satisfactory response under a current of 5 volts. It is a very well made and beautifully balanced instrument, and it also developed an amount of power under 8½ volts, quite sufficient for dental purposes.

3d. *The "Double Induction" Motor.*—This is a small, compact motor weighing but two pounds, six ounces, and, therefore, capable of easy suspension in close proximity to the dental chair. Its cost is but $15, but it requires a high electro-motive force and cannot be run to any advantage with less than from 10 to 12 volts, necessitating a battery of at least six, and preferably seven cells. It should, however, be stated that with a *sufficiency* of power (15 to 20 volts) the capabilities of this little motor are something surprising, and it therefore becomes specially adapted for the direct attachment of circular saws and burs, as illustrated in the engine for both light *and heavy* work in general, oral and dental surgery, as devised by Dr. M. J. Roberts, of New York. As utilized by this engine, the "Double Induction" motor, under a current of 20 volts, will fulfill any demands that can be made upon it. It must be distinctly understood, that the development of power on the part of the two preceding motors under increased volts, is proportionately great, and it was, therefore, deemed necessary that they should have precedence. All of which is respectfully submitted.

J. Foster Flagg, D.D.S., *Chairman.*
Cyrus Chambers, Jr.,
Walter M. James, M.D.,
James Hendrie Lloyd, M.D.,
Charles K. Mills, M.D.,
Samuel Sartain,
C. Seiler, M.D., *Secretary.*

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXVII.—APPLICATIONS OF ELECTRICITY TO WARFARE.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXVII, on Applications of Electricity to Warfare.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR: The Examiners in Section XXVII (on Applications of Electricity to Warfare), respectfully present the following report.

D. P. HEAP (*Ch'n*),
Examiners of Section XXVII.

PHILADELPHIA, *December*, 1884.

TREASURY DEPARTMENT,
OFFICE OF THE LIGHT-HOUSE BOARD,
Washington, November 21, 1884.

SIR:—I have the honor to submit herewith the report of Section XXVII on the applications of electricity to warfare. The exhibit of the Ordnance Department, U. S. N., is the only one containing appliances of this nature. As, however, search lights to be used either on the deck of a vessel or from shore would be useful in warfare, your committee has made a careful report of the best of those exhibited. As chronographs are used to determine the velocity of projectiles, there is included a description and plate of a target used in connection with them, possessing some novel features. The chronographs themselves come under the head of " instruments of precision," and are therefore not described in this report.

Respectfully submitted,

D. P. HEAP, Major of Engineers, U. S. A.,
Chairman Section XXVII.

BRUSH AUTOMATIC FOCUSING LAMP.

EXHIBITED BY THE BRUSH ELECTRIC LIGHTING CO.

This lamp is similar in principal to the well-known Brush lamp, the difference being that both carbons feed instead of one, the upper carbon about twice as fast as the lower. This is accomplished by means of a lever, the short arm of which is attached to the lower carbon, and the long arm to the upper carbon, when the arc becomes too short, the electro-magnet raises the upper carbon and by means of the lever lowers, at the same time, the lower carbon.

The length of the short arm of the lever can be changed so that the proportion between the length of the lever arms can be made to correspond accurately to the rate of the consumption of the carbons to which they are attached. Two guides through which the carbons pass near the focus assure their proper alignment. The whole apparatus is exceedingly simple, well and strongly made, and could be used in a reflector to advantage as a search light. The lamp exhibited is about 4,000 candle-power. D. P. H.

BRUSH HAND FOCUSING LAMP.

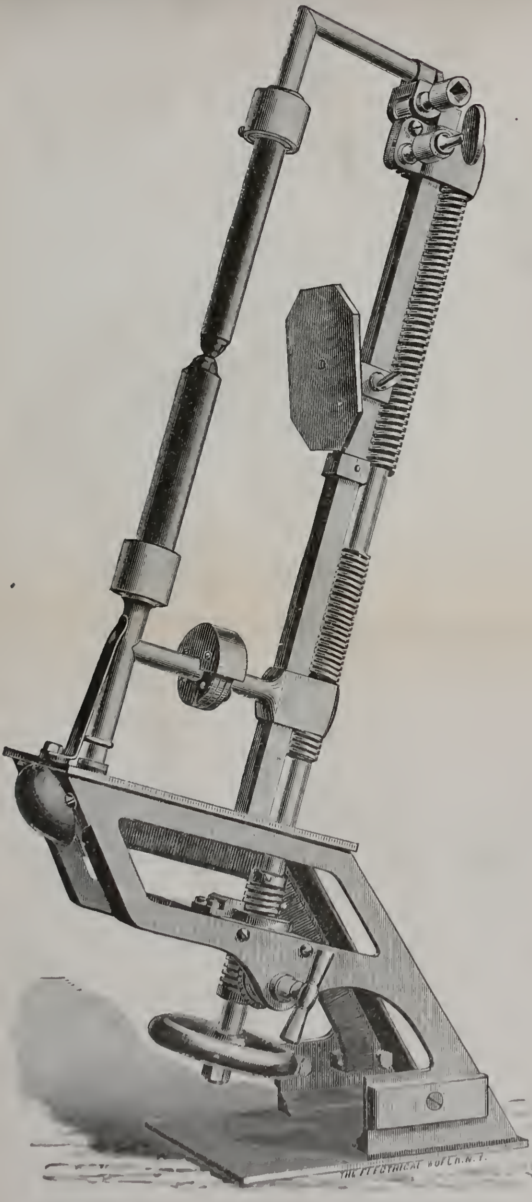
This is the ordinary Brush lamp with the addition of a horizontal wheel by which the whole lamp can be raised or lowered, so as to bring the arc in focus; the upper carbon feeds, the lower is fixed. This lamp was specially designed for use in magic lanterns, in place of the oxy-hydrogen light and generally for laboratory use. It of course needs nearly constant attention to keep the arc in focus. The lamp is well and simply made, and is well adapted for the purpose for which it was designed. D. P. H.

STEAMSHIP PROJECTOR AND FOCUSING LAMP.

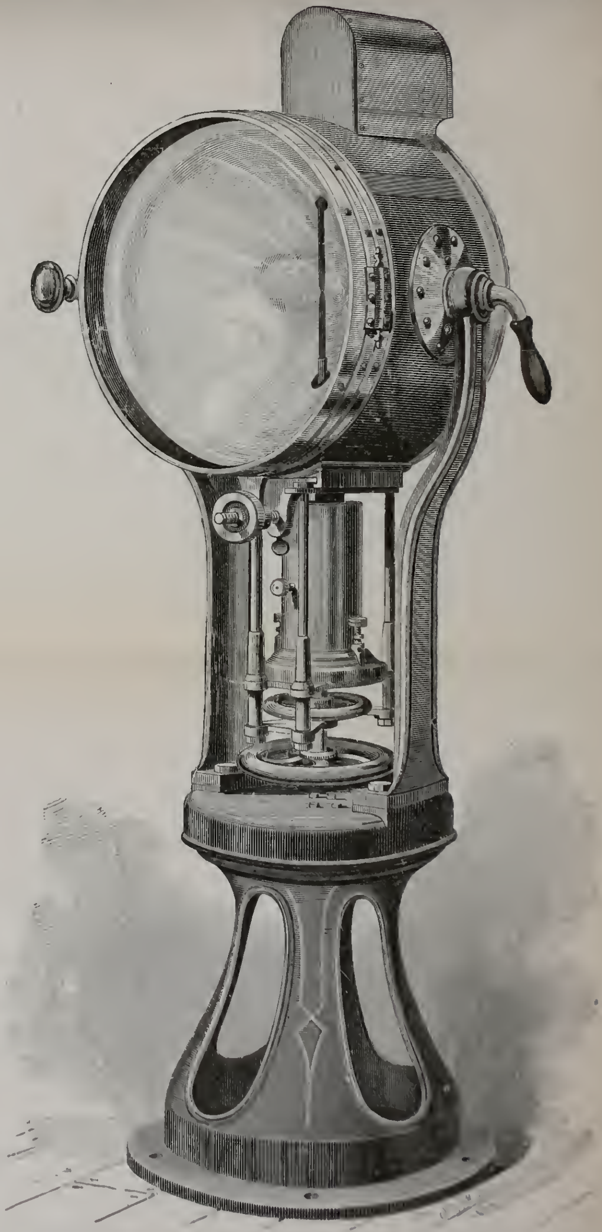
Exhibited by the United States Electric Lighting Company.

This consists of three principal parts, namely, the lamp, the parabolic reflector and the supporting frame. The lamp differs in this particular from the ordinary lamp made by this company; instead of only one, both carbons feed; this is accomplished by means of a cord passing over a small pulley which is attached to the lower carbon, the end of the cord being made fast to the circumference of a larger pulley connected with the feeding mechanism of the upper carbon, the whole being so arranged that the upper carbon will feed about twice as fast as the lower and thus the arc will remain in the focus of the reflector.

A device of this kind is necessary when a continuous current is used, as the upper carbon is consumed about twice as fast as the lower. If an alternating current be used the upper and lower carbons should have the same feed, in this case the two wheels mentioned would be of the same diameter. The parabolic reflector is contained in a metal drum with trunnions supported by the arms of the frame, the lamp is attached to this drum and moves with it. Two handles behind the drum allow it to be moved around a horizontal axis. To one trunnion is attached a handle which clamps the drum in any desired position; the opposite trunnion is hollow, and in it is inserted a piece of ground glass on which the light from the arc falls through a small hole in the reflector, this enables the operator to see that the arc is accurately in focus; a horizontal wheel below the lamp raises or lowers the whole lamp so that if the arc should get out of focus it can readily be brought



Hand-Focusing Lamp of the Brush Electric Lighting Company.



Steamship Projector and Focusing Lamp of the U. S. Electric Lighting Company.

back, there is also a vertical wheel for imparting a horizontal motion to the lamp, either for bringing the arc into focus so as to concentrate the beam or for throwing it out of focus so as to disperse the light and cause it to illuminate a larger space.

The frame is of cast iron and is intended to be firmly bolted to the deck of the vessel, the upper part revolves around a vertical axis and can be clamped in any position, this motion with that of the drum before mentioned allows the light to be thrown in any direction. One man can manipulate the lamp and can readily make all the adjustments, which are within easy reach. The power of the arc lamp exhibited is about 7,222 candles; this, when concentrated in a beam by the reflector, would be greatly increased. D. P. H.

THOMSON FOCUSING LAMP.

Exhibited by the Thompson-Houston Electric Co.

This lamp is the ordinary Thomson lamp, so modified that both the upper and lower carbons feed in about the proportion of two to one. The modification consists in attaching a rack to the rod carrying the upper carbon ; this rack engages a toothed wheel, on the same axis of this wheel and revolving with it is another toothed wheel of half the diameter of the first ; this smaller wheel engages in a rack attached to the rod carrying the lower carbon—hence the upper carbon will feed twice as fast as the lower. (Figs. 1–3.)

Attention is drawn to the following peculiarity in this lamp: The rack is not fixedly attached to the carrier of the upper carbon, but is freely movable between stops *s. s.* (seen in Fig. 3) so that the carrier *R* has a slight independent vertical play between the stops and is lifted by the action of the clutch, when the arc is to be formed without imparting motion to the rack *M* and the lower carrier and carbon. The rack *M* is of sufficient weight to balance the rack-rod and carrier R^2 (Fig. 1) and its accompanying parts, so that no tendency to movement exists unless the carrier *R* and its parts add their weight to that of the rack *M* when the clutch *Y* is released.

The mechanism acts as follows: In Fig. 2, the carbons are shown in the reflector *Y* ready for use, when the clutch is lifted by the magnet system the slight play of the carrier *R* outside of the rack *M* allows the formation of the arc without any movement of the gearing—when the clutch lowers to feed the carbons the weight of *R*, *F* and *E*, etc., is added to that of *M* and causes both carbons to feed at their proper rates by the rotation of the gear wheels. Should, however, the carbons over-feed from any cause and the carbons run too near together, there is at once a renewed lift by the clutch as at first without disturbing the gearing. Fig. 4, exhibits a perspective view of the Thomson Focusing Lamp. D. P. H.

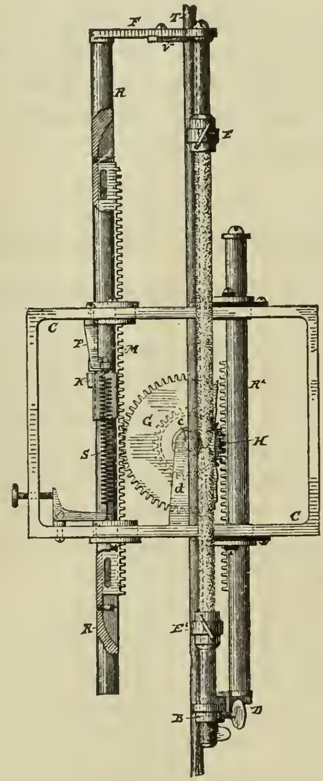


FIG. 1.—Thomson Focusing Lamp. (Details.)

The advantage of this device is that the magnets having but little weight to lift, can act promptly and preserve the electrical balance necessary to a steady light. The position of the arc during burning and the relation of the parts render possible a very compact lamp. It can readily be fitted to a projector the same as described under other systems. The details of the ordinary Thompson lamp are not given here as they properly belong to another section. Drawings and photographs are, however, included for convenient reference.

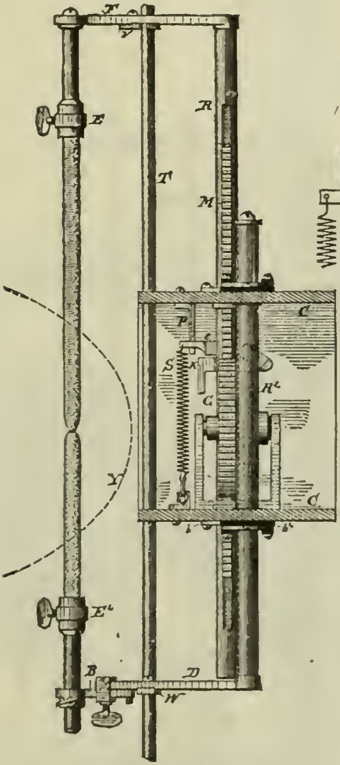


FIG. 2.

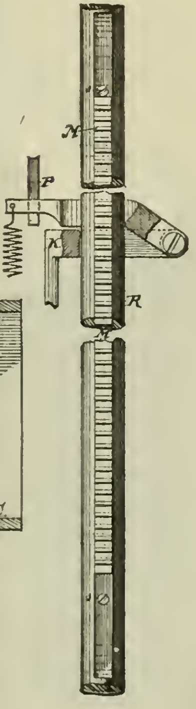


FIG. 3.

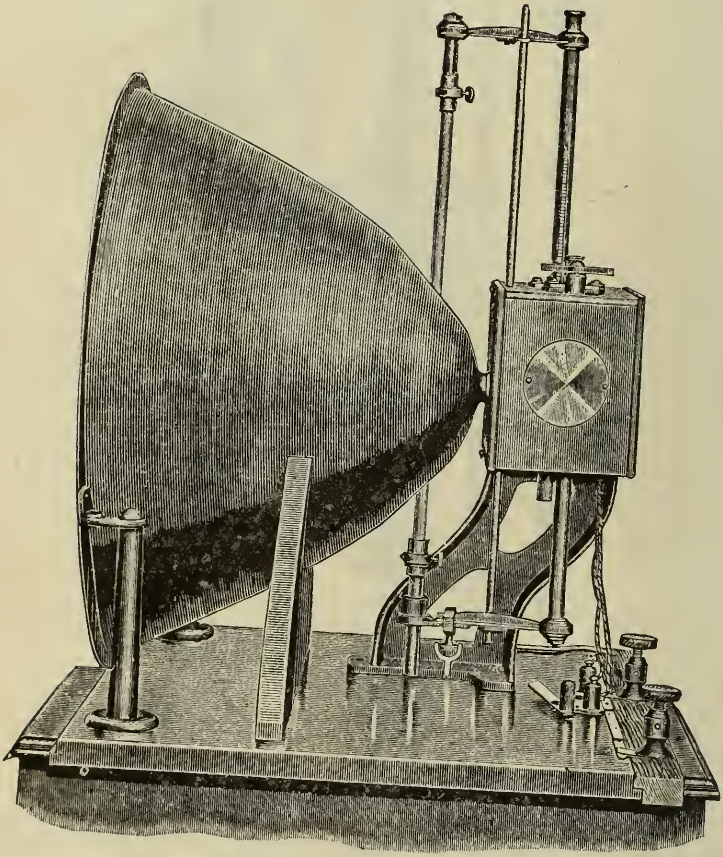


FIG. 4.—Thomson Focusing Lamp.

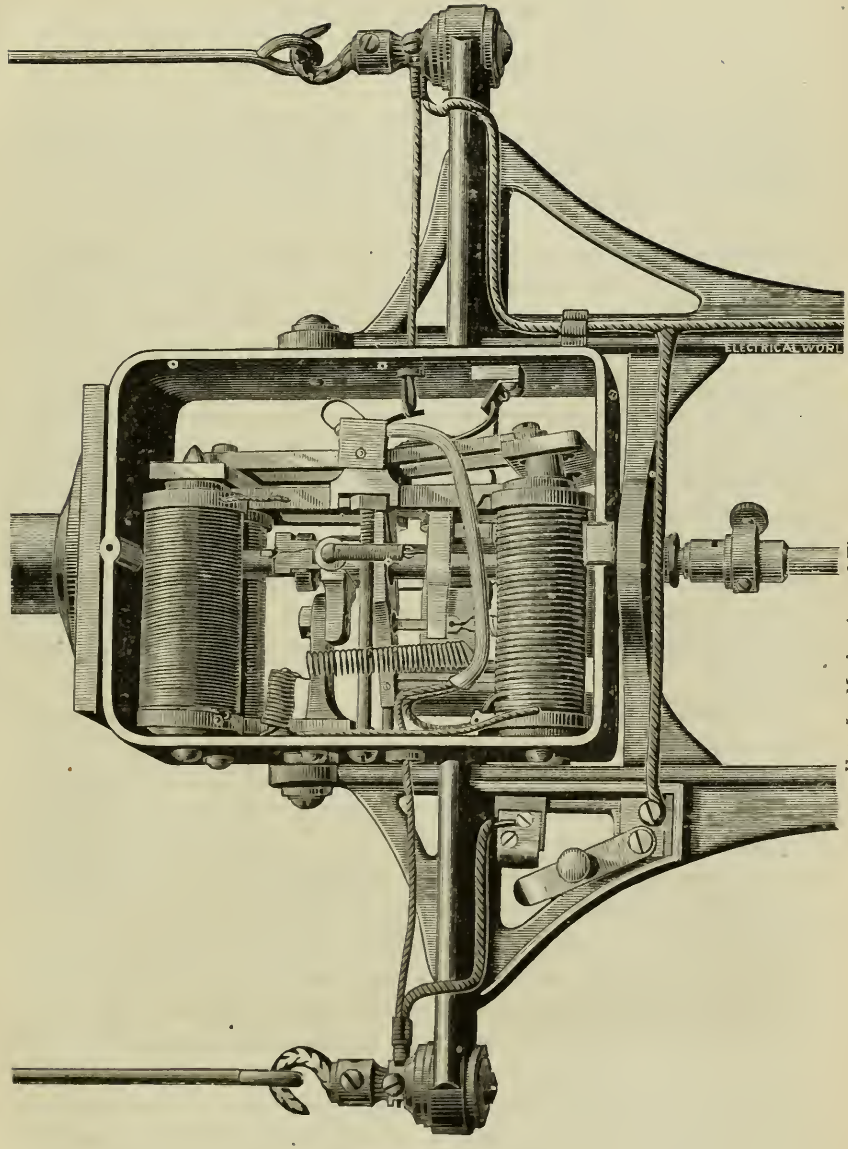


FIG. 5.—Mechanism of Thomson Arc Lamp.

THE MANGIN PROJECTOR.

(U. S. NAVY DEPARTMENT EXHIBIT.)

[NOTE:—The description of this projector is compiled from the reports of Lieutenant T. C. McLean, U. S. Navy, and of Major D. P. Heap, Corps of Engineers, U. S. A., on the International Exhibition of Electricity held in Paris in 1881. The plates are also taken from the same reports.]

Before the invention of this projector, the lenticular and the parabolic were used, the former is not only costly but also to some degree absorbs the light: the latter form is difficult to obtain with precision. It was these considerations which led Colonel Mangin to seek a new form, which he has happily found in a spherical glass mirror of special construction. In the ordinary spherical form, the spherical aberration interferes with its use when the light is projected to a distance, Colonel Mangin has ingeniously corrected this defect; he uses a glass mirror, the reflecting surface of which is on the convex side, thus the ray traverses twice the thickness of the mirror before taking its final direction. Now, these two surfaces are not parallel, the interior surface being a sphere having a different radius than the other, or in other words the mirror is a concavo-convex lens with the centre thinner than the edge.

The different thicknesses which the various rays have to traverse, according to the angle which they make with the axis, so modify them as to bring them rigorously parallel if the radii of the two surfaces of the mirror are in proper proportion. The Voltaic arc is peculiarly well adapted for use with such apparatus as it approaches most nearly the character of a luminous point. The lamp used is exceedingly simple and needs but little description in addition to the plates. It will be noticed that the carbons are inclined. This is because where a continuous current is used, the maximum intensity of the light is not in a plane perpendicular to the line of the carbons, but in one about 30° below. A small mirror, or sometimes a carbon plate is placed in front of the carbons to throw the light on the reflector. The cylindrical body of the projector is mounted on trunnions, and the trunnion supports are fixed on a cap which is so pivoted on the base of the apparatus that the beam of light may be thrown in any direction desired. Clamps are provided at the right trunnion and at the base pivot for retaining the projector in any position for steady direction. The holes in the

Fig. 1.

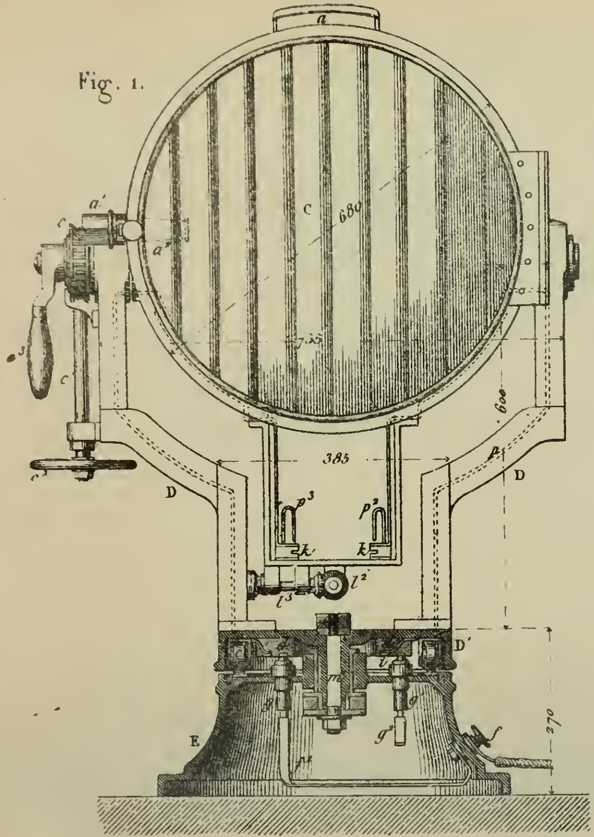
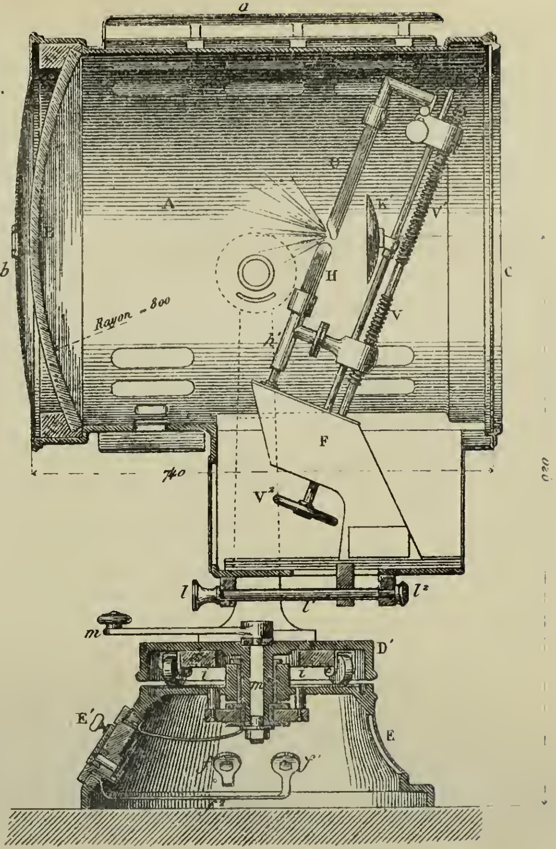
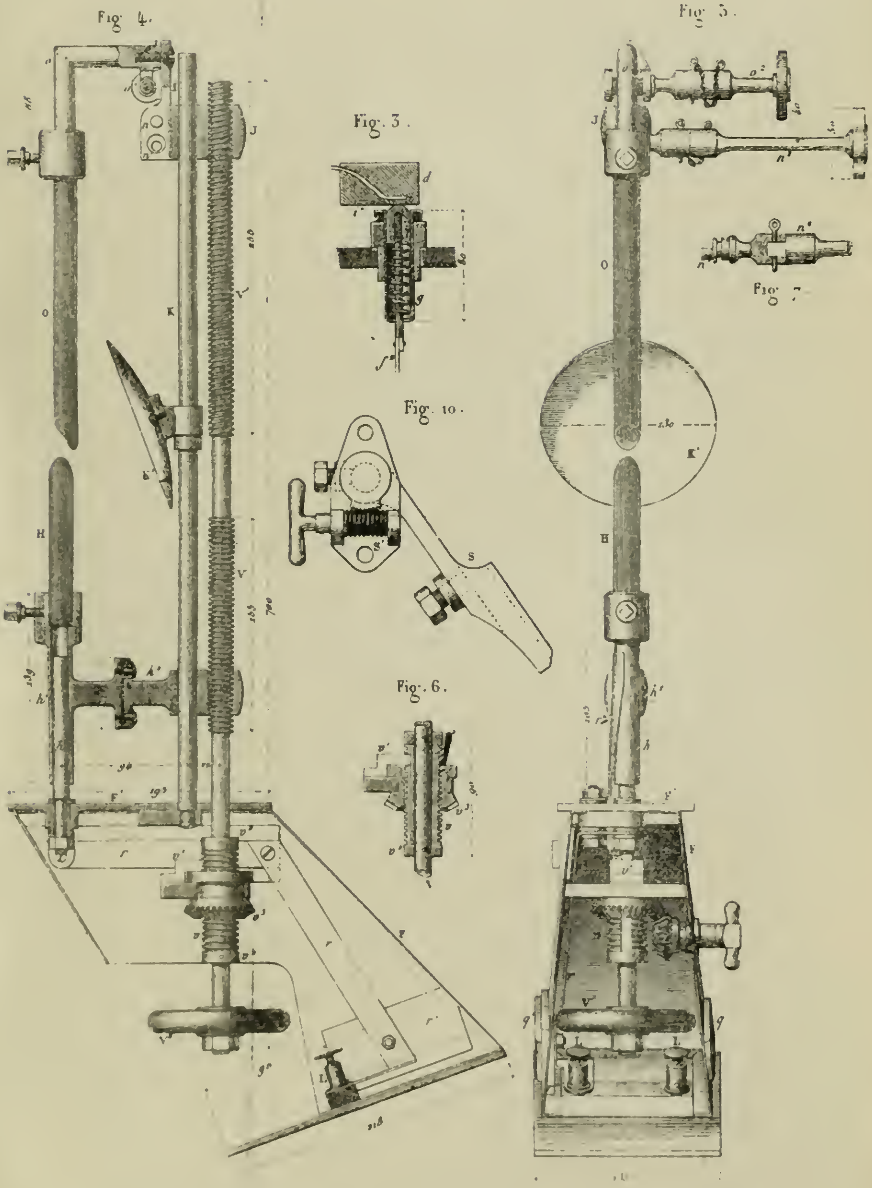


Fig. 2.



THE MANGIN PROJECTOR. (PLATE I.)



THE MANGIN PROJECTOR. (PLATE II.)

[DETAILS OF HAND LAMP.]

cylindrical body are for ventilation. The glass door is made in strips so that a crack at any one point will not extend through the whole.

The various details of the lamp and projector are clearly shown in the accompanying drawings.

Plate I, figs. 1 and 2 represents respectively front and longitudinal sectional views of

The Mangin Projector.

[Dimensions given in millimeters.]

A. Drum containing lamp and spherical reflector.
B. Spherical reflector.
C. Front of projector enclosed with vertical stripe of glass.
D. Supporting arms carrying drum.
E. Base of apparatus showing electrical connections.

Plate II, figs. 3 to 10 gives the details of hand lamp.

[Dimensions given in millimetres.]

Fig. 3. Shows electrical connection of wires from lamp to wires in base.

Fig. 4. Side view of hand lamp.

Fig. 5. Front view of hand lamp.

Fig. 6. Details of device for raising or lowering both carbons simultaneously.

Fig. 7. Device for giving the upper carbon a backward and forward motion by means of the eccentric pin *n*.

Fig. 10. Details of device for giving lateral motion to upper carbon.

THE McEVOY TORPEDO DETECTOR.

This is a modification of the induction balance. It consists of a sinker, which is a heavy case containing two coils of fine wire in separate circuits, a cable containing four insulated wires which are connected to both ends of the coils, and a box which holds two coils, each one of which is in series with one of the coils in the sinker, and connected to them by the four wires in the cable. The box is designed to be carried in a boat, from which the cable hangs. One of the coils in the box, and its corresponding coil in the sinker are in circuit with a small battery and an automatic circuit-breaker, which is also in the box. The whole forms a primary circuit of which the secondary consists of the two other coils and a telephone receiver in circuit with them.

When now the current in the primary is closed, the intermittent currents in the primary coils induce currents in the secondary coils, but the secondary coils being wound in opposite drections, they can be so adjusted that the induced currents neutralize each other, so that no sound is heard in the receiver. If, now, the boat is pulled slowly through the water and the sinker is thus dragged along the bottom, no noise will be heard in the receiver unless the sinker come into proximity with some mass of magnetic metal, such as a torpedo case. In this event, however, the number of lines of force enclosed by the coils in the sinker will be greater than the number enclosed by the coils in boat, the induced currents from the former coils, will overpower those induced in the latter, and a humming noise will be heard in the receiver.

The apparatus shown at the exhibition did not seem to be sufficiently sensitive; but there seems no reason for believing that an apparatus on this principle could not be made very sensitive by using much larger coils and a very strong battery.

[Here follows a description of McEvoy's Electro-Automatic Mine, taken from the report of Lieutenant T. C. McLean, U. S. N., on the Paris Electrical Exhibition of 1881. This the committee does not deem it necessary to republish.—Ed. Com.]

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